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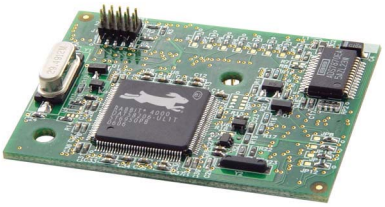

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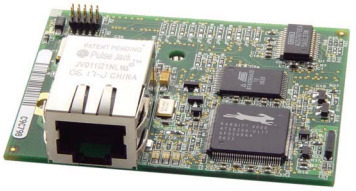

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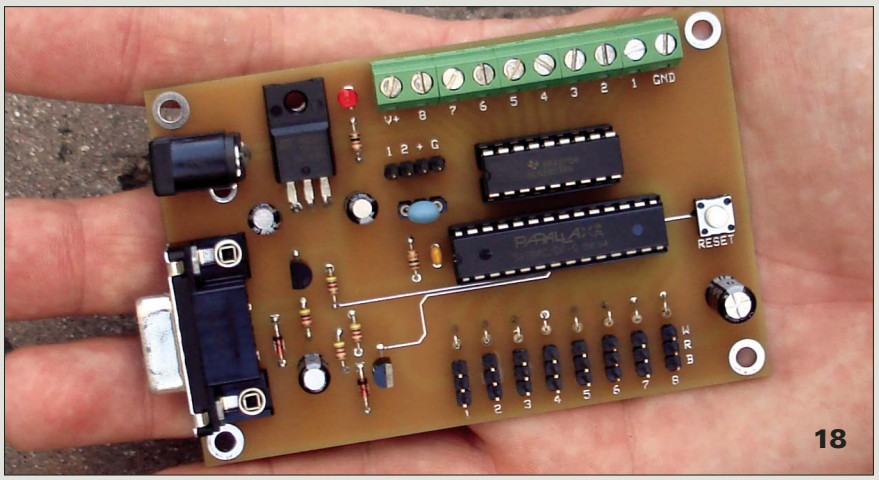

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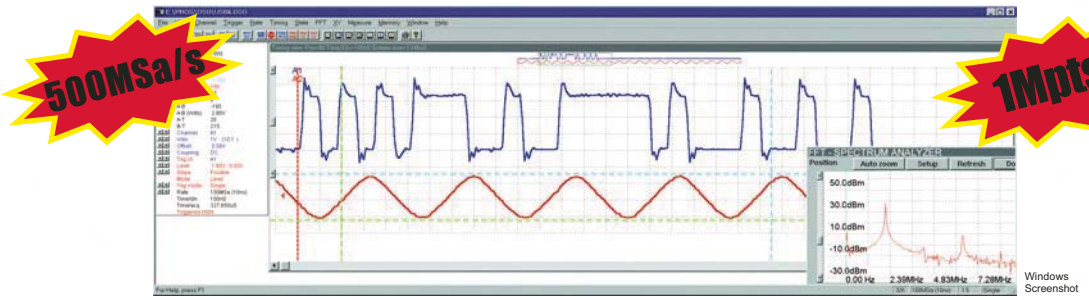

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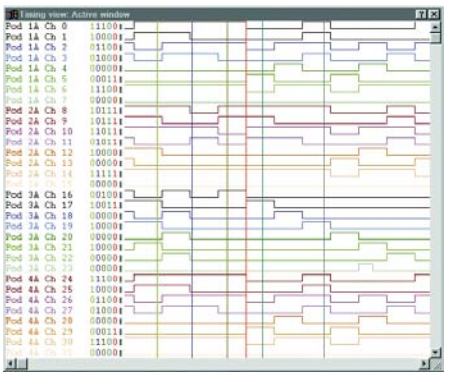

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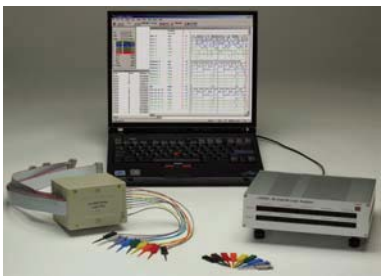

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READER FEEDBACK

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EVERYTHING FOR ELECTRONICS

THUMBS UP FOR ANEMOMETER

Just wanted to say I really enjoyed the article by Michael Simpson on making the anemometer. I don't know of any hobbyist who hasn't attempted or at least thought of making a home weather system.

Dan Bacon

MISSING FEATURES ON POWER SUPPLY

Robert Reed's interesting article on a Test Bench Power Supply (March 2007) includes many desirable features and a number of clever ideas. I am troubled by what I consider to be two fundamental problems:

1. The inability to adjust the maximum current means you cannot use the device to conveniently test diodes (especially LEDs), or to recharge Nicad or similar batteries.

2. The unit is not designed for a typical use at five volts at near full current. The unit will overheat at this load, and the output voltage will cycle as the regulator goes into and out of thermal overload (as noted by the author). When working on a circuit on the bench, one does not want to be worrying about the power supply overheating!

I built a dual bench supply in 1966 (from a *73 Magazine* article), which has both adjustable voltage and current, and still use it daily. The adjustable current is a feature I simply could not do without. I'd like to see a follow-up article by this obviously talented author, which adds current adjustment (perhaps another LM317) and better heat control.

Paddy Johnson

Response: Well, let me see. Where do I start? As to item one, current limiting and constant current were deleted from design for reasons stated in the article. The supply was not meant to be a battery charging device, as with today's myriad of special batteries this would demand quite a variety of safety measures built in. Nor was it intended to be a component tester either. However, the reader has two choices on these options: 1) Go to National Semi's website and download the LM317 data sheet. There you will find additional info on the LM317 as a current source that you may want to incorporate into this design. 2) An outboard constant current source is a very simple circuit to build requiring one transistor and a couple of resistors. These options were deleted from design for several reasons as mentioned in the article: simplicity, compactness of size, and personal lack of desire for these options.

As to item two, I don't know if I understand the question correctly, but the 5 VDC supply is rated for one ampere of current and the article states the heat dissipation is well within the devices range, as verified by actual case temperature measurements, and this was with all supplies loaded. In fact, I have actually run any of the outputs at 1.5 amps for short periods of time (15-20 mins.) and experienced no problems. Does the reader understand that all devices are heatsinked to the chassis? I hope this answers the readers questions satisfactorily.

Robert Reed

ENCLOSURE ENQUIRY

The Test Bench Power Supply article was wonderful, informative, and the photos were of exceptionally high quality. Many details are included, but extremely little is said about the methods to be used in working the aluminum to form the enclosure. In particular, how do you cleanly cut out the rectangular holes for the meters in the front panel?

Judy May
Union, KY

Response: Well for starters, like most people who lack a machine shop for metal work, I did it the slow way. For bending the sheet metal, I jury-rigged

Continued on Page 35

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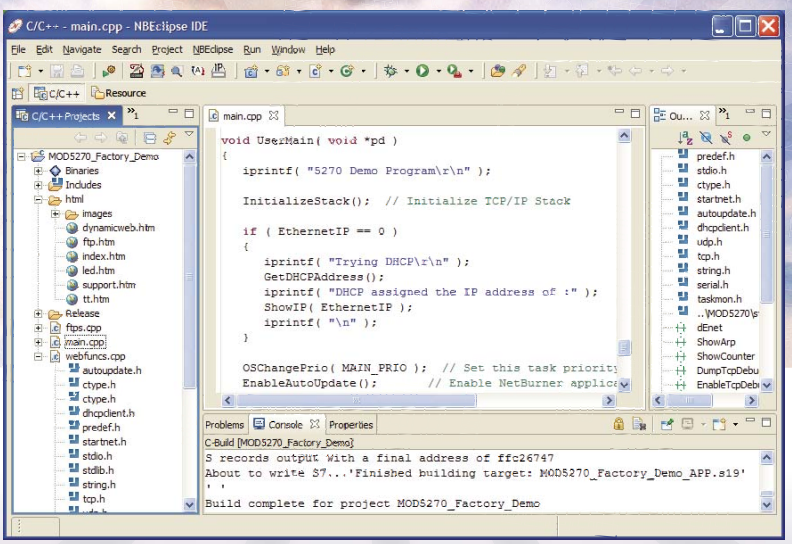

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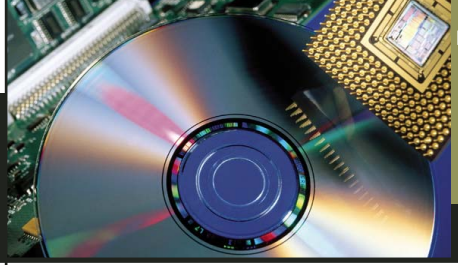


TECH KNOWLEDGEY 2007

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

COATING MAY IMPROVE SOLAR CELLS, LEDS

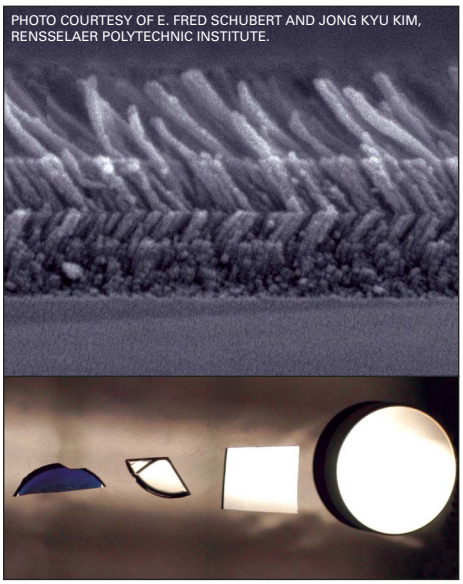


PHOTO COURTESY OF E. FRED SCHUBERT AND JONG KYU KIM, RENSSELAER POLYTECHNIC INSTITUTE.

■ Top: Silica nanorod layers seen with a scanning electron microscope. Bottom: Antireflective material (left) looks dark in contrast to other coatings.

A team from Rensselaer Polytechnic Institute (**www.rpi.edu**) recently reported development of an antireflective coating that is said to be at least ten times as effective as substances currently used on sunglasses and computer monitors. Composed of silica nanorods, it could be used to channel light into solar cells or improve the photonic emissions of LEDs.

The coating is produced by a process that is based on a common method for depositing silica layers onto computer chips, but it involves growing tiers of nanoscale rods that lie at the same angle, the precise angle being determined by temperature. By laying down multiple layers at different angles, the researchers have generated thin films that can be used to control light.

It is believed that by creating layers in the proper configuration, it is possible to create a film that will reflect no light at all. If used in next-generation solar cells, the coating would allow more light and more wavelengths to pass through the cell surface, thus improving its efficiency.

The team also expects that the films can be used to eliminate reflections that reduce light emissions from LEDs, so upcoming research will focus on solid-state lighting applications.

"TRICORDER" REALIZED?

Some researchers at Purdue University (**www.purdue.edu**) recently developed a new instrument that they have likened to the infamous "tricorder" from *Star Trek*. My recollection is that the fictitious device was useful for everything from analyzing the chemical makeup of alien brains to opening cans of intergalactic Vienna sausages, so the analogy may be a bit overstated. However, it is an interesting chemical analysis tool that they say has promise for detecting "everything from cancer in the liver to explosive residues on luggage and biomarkers in urine" to provide an early warning of diseases.

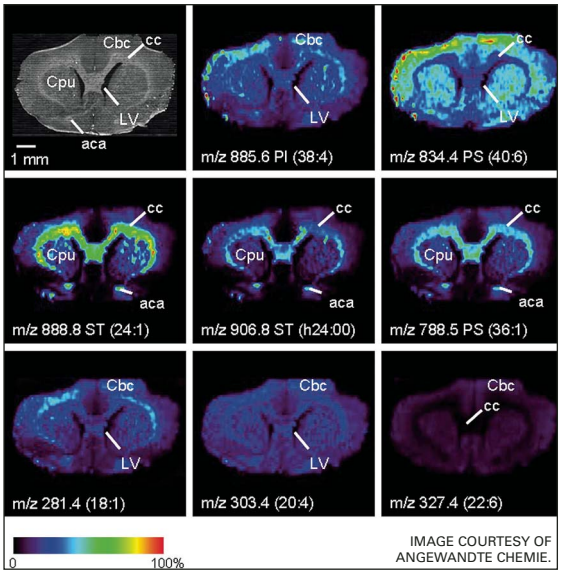


IMAGE COURTESY OF ANGEWANDTE CHEMIE.

■ Analysis of lipids in rat brain tissue. The first (a) is an optical image, and the rest are ion images produced using the DESI technique.

The device is a compact mass spectrometer that is enhanced by a technique called desorption electrospray ionization (DESI), developed at Purdue. Whereas conventional mass spectrometers analyze samples that are loaded into a vacuum chamber, DESI allows an analysis to be performed in air or directly on the sample's surface. The new device is also much smaller than standard analyzers, weighing less than 20 lbs, and does its work in a relatively short time.

For example, the team has used the device to analyze clothes, foods, and tablets, and it can identify cocaine on paper money in less than one second. It is likely that the device will be commercially available soon, as two companies have already been established on the basis of DESI and the portable mass spectrometer. These are Prosolia, Inc. (**www.prosolia.com**), and Griffin Analytical Technologies LLC (**www.griffinanalytical.com**).

COMPUTERS AND NETWORKING

POSSIBLE JPEG SUCCESSOR INTRODUCED

For 15 years or so, you have probably been working with the familiar JPEG format for digital imaging, especially with devices that use a memory card for storage. However, if Microsoft has its way, JPEGs may follow PICT files into obscurity, being supplanted by their HD Photo format (formerly known as Windows Media Photo).

The product was formally introduced in March, and it is

said to offer up to double the compression efficiency of JPEG with fewer damaging artifacts, which results in higher quality images that are only half as large. In addition, the technology offers increased image fidelity, preserving the entire original image content (i.e., "lossless compression") and enabling improved exposure and color adjustments.

The format does not seem to have generated a great deal of software support so far, but Microsoft has announced the beta release of a set of HD Photo plug-ins for Adobe® Photoshop®, developed with the help of Adobe Systems, Inc. The plug-ins support both the CS3 and CS2 versions of Photoshop software and will be available for Windows® Vista™ and XP, as well as Mac OS X. By the time you read this, they should be available — for free — from **www.microsoft.com/downloads**.

ANOTHER NEW SEARCH ENGINE

If you thought the World Wide Web had enough search sites, meet hakia Galleries (**www.hakia.com**), an innovative "meaning-based" engine. It delivers categorized search results (the galleries) in response to a short query, providing the equivalent of 10 search variations.

The hakia Galleries cover a range of topics, including diseases, company profiles, data about cities and countries, and famous people. Current examples of the hakia Galleries (there are said to be thousands available already) include Anna Nicole Smith, Pokemon, Tokyo, Red Sox, cancer, chocolate, Vioxx, cello, and George Washington. And the engine will keep getting better, as the coverage of hakia Galleries is slated to expand continuously throughout 2007 via an automated "distillation" algorithm.

802.11N UPGRADES AVAILABLE

If you happen to be the owner of an Intel-based Mac that was built before Apple started putting 802.11n wireless network cards in them, you now have an alternative to living with the older, slower WiFi capabilities. For $149, QuickerTek, Inc. (**www.quickertek.com**), will sell you an upgrade card or — for $199 — will install it for you.

The cards are made to the same specs as the Apple products and fit into the AirPort slot. They work with all 802.11/b/g/n WiFi equipment, including AirPort and AirPort Extreme. They are compatible with all of the newer 17-, 20-, and 24-inch iMacs, as well as pre-802.11n MacBooks and MacBook Pros, but you'll need to be running OS X 10.4.8 or later.

CIRCUITS AND DEVICES

INSTRUMENTS INCLUDE TEMPERATURE MEASUREMENT

PHOTO COURTESY OF EXTECH INSTRUMENTS.

■ Extech's meters feature built-in IR temperature measurement.

If you need to, for example, test a high-voltage breaker box or make physical contact with an active electric motor, it can be pretty handy (and a lot safer) if you can first point something at the target area and check for hot spots, given that large temperature rises may indicate problems with motors and circuits. A noncontact infrared thermometer would do the trick, but who wants to carry around an extra instrument?

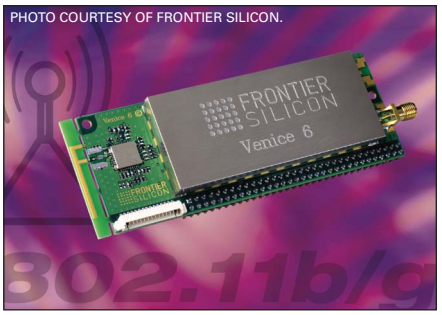
That's the basic idea behind a series of test instruments from Extech Instruments (**www.extech.com**). The company originally introduced a patented line of digital multimeters with the thermometer included, but now also offers a clamp meter, tachometer, anemometer, humidity psychrometer, and hygro-thermometer, all using IR technology.

The thermometers incorporated into the Extech products feature a temperature range as low as -58°F (-50°C) to a high of 932°F (500°C), and a built-in laser pointer allows a user to pinpoint the target area. This is particularly useful for small targets and hard-to-reach areas.

The cost isn't exorbitant, either, so you might want to consider the EX470 multimeter, for example, which sells for about $125. If nothing else, you can check the temperature of your beer from across the room with it.

FOUR-IN-ONE MODULE

PHOTO COURTESY OF FRONTIER SILICON.



■ The Venice 6 provides four types of audio in one module.

An interesting new chip from Frontier Silicon (**www.frontier-silicon.com**) is the Venice 6, billed as the world's first four-in-one module capable of receiving Internet radio, digital audio broadcasting (DAB), FM, and music streamed from a PC. It integrates a WiFi, DAB, and FM front end with an on-board WiFi antenna, enabling audio manufacturers to build a new generation of versatile radios for the global market.

Based on Frontier's Chorus 2i processor, the device streams radio stations and music files in several formats and protocols, including MP3, WMA, and Real Audio. It provides access to over 10,000 Internet radio stations plus a wide selection of podcasts with only a few key presses, accessed through a vTuner Internet Portal that manages all the stations.

A company representative noted, "Audio manufacturers want to build products that can be used and sold anywhere in the world. With the

INDUSTRY AND THE PROFESSION

NRAO CELEBRATES 50TH

■ The GBT, located in Green Bank, WV, weighs 16 million pounds, has a surface area of 8,000 square meters, and is taller than the Statue of Liberty.

In case you weren't keeping track, the National Radio Astronomy Observatory (NRAO, **www.nrao.edu**) turns 50 this year, and they will be observing the occasion at the Science Symposium June 18-21. Its official title is "Frontiers of Astrophysics: A Celebration of NRAO's 50th Anniversary," and the event will be held at the Omni Charlottesville Hotel in Charlottesville, VA. The scientific program has not been announced as of this writing, but a downloadable poster mentions such subjects as cosmic microwave background, dark energy and dark matter, extreme gravity, and the origin of cosmic structure and galaxy evolution.

Registration will run you $350, which includes a reception, coffee breaks, lunches, and a poster session reception. Also offered (separately) is a tour of the NRAO Green Bank, WV, facility, which houses — among other things — the Robert C. Byrd Green Bank Telescope (GBT), said to be the world's largest fully steerable single-aperture antenna (see photo).

GATES WINS AGAIN

In case you were worried about it, rest assured that Bill Gates has once again come out on top of the *Forbes* magazine (**www.forbes.com**) list of billionaires, with a net worth of $56.0 billion. Next in line is investment guru Warren Buffet, with $52.0 billion, but both are losing ground to Carlos Slim Helu, a Mexican telecommunications mogul who has $49.0 billion ($19 billion more than last year).

The sad news is that Gates' buddy Steve Ballmer dropped in ranking from 24th to 31st, although his holdings actually grew from $13.6 to $15 billion. Other heavy-walleted folks from the electronics industry include Oracle's Larry Ellison ($21.5 billion), former Microsoft guy Paul Allen ($18 billion), and Michael Dell ($15.8 billion). Steve Jobs, with a paltry $5.7 billion, didn't even crack the top 100. Oh, well.

fragmentation of broadcast radio standards, this has been a difficult goal to achieve — until Frontier introduced the Venice 6 module." Indications are that the device will be appearing in radios, small CD systems, boom boxes, and HiFi tuners sometime in July.

5 MPIXEL SENSOR INTRODUCED

Eastman Kodak Co. (**www.kodak.com**) has changed quite a bit from the days of Brownie cameras and Plus-X film, and its latest venture into the digital world takes the form of the KAC-05010 5.0 megapixel CMOS image sensor aimed for digital still cameras and mobile phones. The 2.2 micron pixel, 1/2.5 format sensor is said to offer improved image quality, lower noise, and top-notch color reproduction.

The sensor incorporates the company's PIXELUX technology, which is an architecture that uses pinned photodiodes and a four-transistor shared pixel structure to produce lower noise. It also includes charge-domain binning of multiple pixels on the imaging array for higher sensitivity and 30 frame/sec video recording.

The KAC-05010 is now available in samples, with production quantities to be available at an unspecified time. Kodak also offers products for the automotive and industrial imaging markets. **NV**

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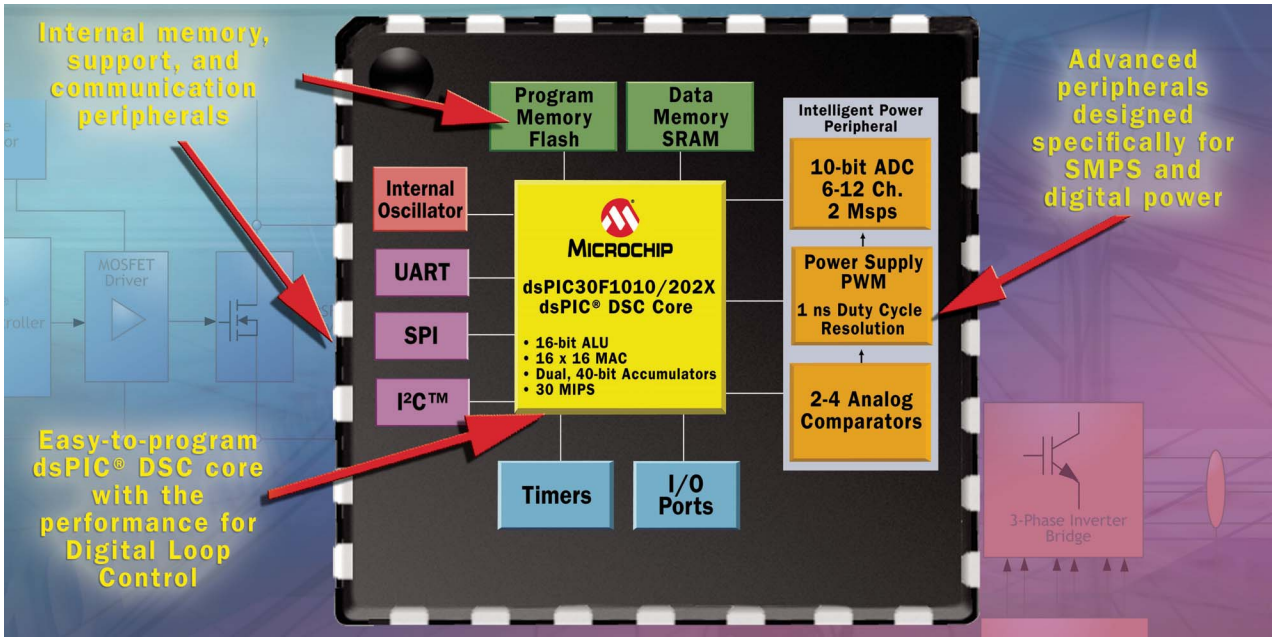

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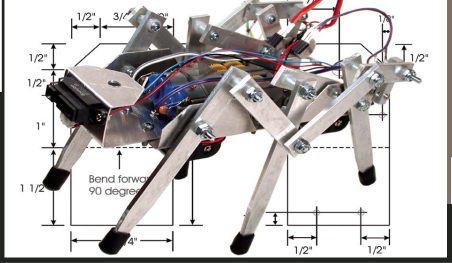


■ BY PHIL DAVIS

PARAMETERS ON THE FLY: Part 3

THIS MONTH, I WOULD LIKE TO WRAP UP the design and functioning of the Hand-Held Console by showing you the completed device and by posting the software online for all to use.

The idea behind this device is to allow the changing of those variables which are typically used to tune or control the robot. For example, if you have a robot that is designed to stop four inches from a wall, then you will probably have a distance sensor and a variable containing 4 and the bot will stop when the distance sensor matches the variable. However, when building your robot you find that due to inaccuracies in the distance sensor, your robot actually stops six inches from the wall. Typically, the only way to fix this is to edit your code, recompile the program, and download in into the robot. You might find you have to do this many times to get it just right. With the Hand-Held Console we are building, you will be able to do this on-the-fly, without having to change the code.

PHYSICAL LAYOUT

In the previous articles, I talked about most of the components which go together to build this device. The first of these is, of course, the frame which is made out of 'white board' and cut on a laser printer. As you can see in Photo 1, there is a hole cut for the LCD, a small slot just beneath that for the keypad cable, and a series of holes for your fingers to get a good grip.

In Photo 2, you can see the front of the console with the LCD installed and the keypad 'stuck' onto the surface. This particular keypad comes with a self-adhesive back; just peel off the cover and press in place. It also has a ribbon cable which plugs directly into the LCD and can then be read off the I^2C from the processor board — very simple and easy. Also note on the top left the on/off switch and the two momentary switches for controlling the functions. Sticking up from the back at the top is the rubber duck antenna from the A7 Engineering's EB501 Bluetooth device.

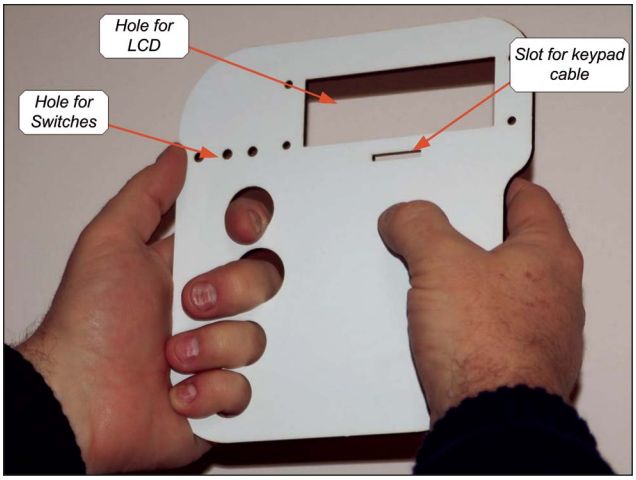
You may have noticed that the console is no longer white. Jerry — who cuts the white board on his laser (see the Resources sidebar if you need something or this console cut) — decided to spray paint it silver. The paint had some strange reaction with the white board — probably an oil layer — and formed an odd textured pattern. I liked it, so I kept it.

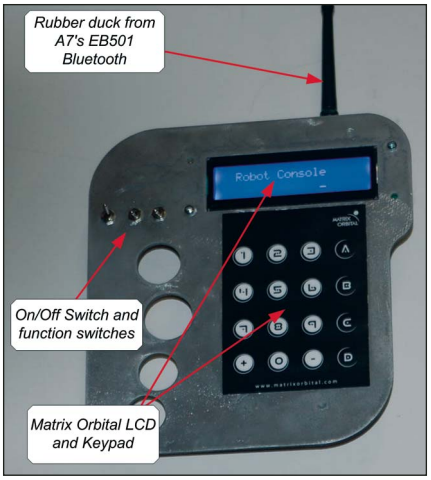
Looking at the console from the back in Photo 3, you can see how that various components are arranged. The LCD is secured in place via screws through the laser cut holes, however, the rest of the components are held in place with double-sided tape. There is no real stress on these components and it saves putting holes through the white board, especially where the keypad is. The LiPol Battery is held in place with Velcro®, allowing removal for charging.

Photo 4 is a quick shot of the console being held with both hands just to test the usability and position of the components. Seems to work very well!

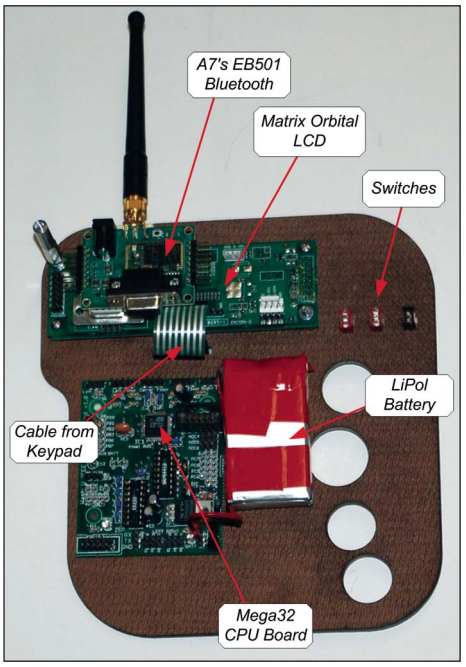
I have been using two different Bluetooth modules for this project. One is the "Embedded Blue" product offered by Parallax and the other is the EB501 offered by A7 Engineering. The EB501 is a good fit

■ PHOTO 1. White board cut out.

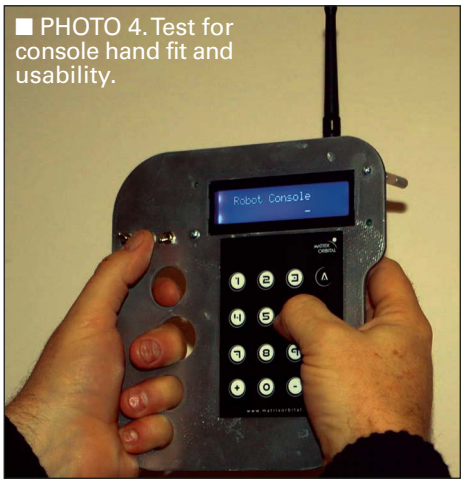




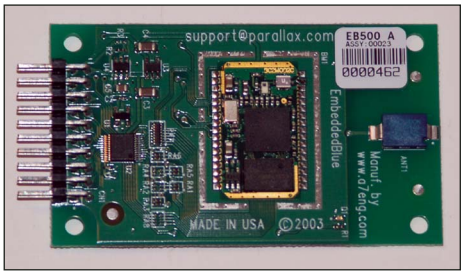
■ PHOTO 2. Console front with components installed.



■ PHOTO 3. Components secured on the back of the console before wiring.



■ PHOTO 4. Test for console hand fit and usability.



■ PHOTO 5. Embedded Blue from Parallax.

for the hand-held portion of the console. However, if you are using Parallax products (or any other), the Embedded Blue product is a great fit for onboard the bot. Photo 5 shows Parallax's Embedded Blue product.

PROTOCOL CODE

Last month, I discussed the need to be able to transmit non ASCII code back and forth and still be able to wrap the data in a packet. To do this, I wrote a couple of small routines to encapsulate the packets and to place a 'marker' byte in front of any byte which would conflict with the start and end of the packet.

The sendPacket routine is the simpler of the two and places a header, marker bytes, and trailer in the packet. Figure 1 shows this simple piece of code.

The code to receive the data is slightly more complicated because we need to wait for the beginning of a packet — ignoring everything else — check for marker bytes and then wait for the end of the packet, storing everything in between. In addition, we only want to wait a finite time. Consequently, we want to pass a parameter to use as a 'time out.' In other words: "Go get me a packet, but if you don't get one in say, two seconds, just come back." Check out Figure 2. Allowing the process to time out like this will safeguard us against noise or the bot switching off or getting out of range, etc.

OPERATION

As discussed in the previous months, the protocol portions of code must be added to the bot, as well as the console. The protocol portions are symmetrical, however, layered on top of the protocol is code that makes the bot respond to the console and, of course, the console respond to the user and to the bot.

```
void sendPacket(BYTE *pac, int len) {
    int i;
    BYTE j = 0;

    sndBuf[j++] = STX;
    for (i=0; i<len; i++) {
        if (pac[i] == SOH || pac[i] == STX || pac[i] == ETX)
            sndBuf[j++] = SOH;    //  Mark if a special char
        sndBuf[j++] = pac[i];
    }
    sndBuf[j++] = ETX;

    UART_Send_Msg(sndBuf, j);
}
```

■ FIGURE 1. Code to packetize the data.

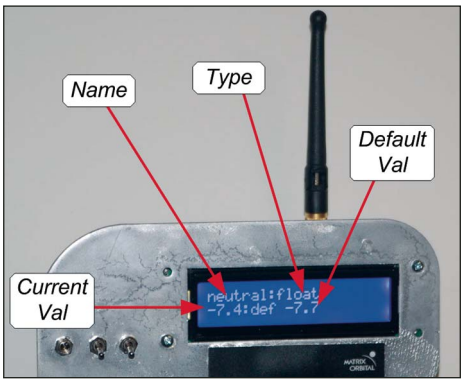
```
int waitForPacket(BYTE *pac, portTickType to) {
    int i = 0;
    bool   start = FALSE,
    bool   SOHon = FALSE;
    int    ch = 0;
    portTickType    xstartTime;

    xstartTime = xTaskGetTickCount();     // Get initial time
    while (1) {
        ch = UART_RxInt();
        if (ch == -1) {                   //  no char available
            if (to < (xTaskGetTickCount() - xstartTime))
                return -1;                //  times up -- Time Out
            taskYIELD();                  //  yield for a bit, until a char arrives
            continue;                     //  go round again
        }
        if (ch == STX && !start) {        //  really found start of packet
            start = TRUE;
            continue;                     //  go round again for the first char
        }
        if (start) {                      //  start grabbing bytes
            if (ch == ETX)    {           //  end, so return with length
                return i;
            }
            if (ch == SOH && !SOHon) {    //  is this really a mark byte
                SOHon = TRUE;             //  if so, set flag
                continue;                 //  go round again and grab the marked byte
            }
            SOHon = FALSE;                //  only use this this once
            pac[i++] = ch;                //  store message byte in buf
            continue;                     //  go round again
        }
        if (to < (xTaskGetTickCount() - xstartTime))//  we only get here for byres outside a packet
            return -1;                    //  times up -- Time Out
    }
    return -1;
}
```

■ FIGURE 2. Code to wait for a packet, timing out if not received.

■ PHOTO 6. Console searching for a bot.

■ PHOTO 7. Console indicating it is ready and the number of parameters uploaded.



■ PHOTO 8. Console displaying an uploaded float parameter.

When the console is first switched on, its first function is to search for the bot. It does this by having the Bluetooth module look for the address of the bot which I have currently hard coded in. Future versions should display the addresses of bots found and let you choose from the list.

Having found the bot, the console requests that the bot respond with the list of parameters. At this point, the console displays the name of the bot associated with the address (the Bluetooth modules allow you to change their 'name') and the number of parameters uploaded. See Photo 7.

The parameter information that we are currently maintaining is:

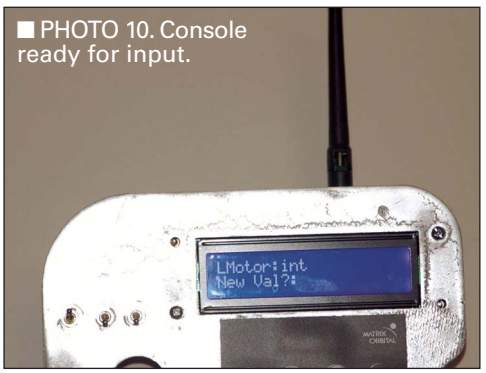
- Parameter name
- Parameter type (i.e., int, float)
- Default value
- Current value

By toggling the first momentary switch, the console is designed to scroll through all of the uploaded parameters displaying the above details of each, as shown in Photo 8. Toggling the first switch switches to the next parameter and then by toggling the second momentary switch, the console will allow the user to change the value of the parameter currently displayed. Please see Photos 9 and 10.

The user now has the ability to key a new value using the keypad and, when complete, toggles the second momentary switch again. This tells the console to send the changed parameter to the bot and wait for a response.

■ PHOTO 9. Console displaying an uploaded int parameter.

■ PHOTO 11. Console confirming parameter change.



■ PHOTO 10. Console ready for input.

When the bot responds that the change is complete, the console displays the final message of the series confirming the edit. See Photo 11.

So, that's it. Using the console, you can flip through the various parameters you have set up to allow modification and change them on-the-fly. This is not designed to remotely control your robot, but rather to make it easier to program and set up.

SUMMARY

I think this is one of the more useful tools I have developed for my personal robots. It has the potential to save lots of time in the future and certainly makes it easier to fine-tune your robots behavior. **NV**

RESOURCES

■ *Matrix Orbital LCD* — **www.matrixorbital.com**

■ *EmbeddedBlue* — **www.parallax.com**

■ *EmbeddedBlue* — **www.a7eng.com**

■ *FreeRTOS* — **www.freertos.org/**

■ *WinAVR* — **http://winavr.sourceforge.net/**

■ *AVRstudio* — **www.atmel.com/dyn/products/tools_card.asp?tool_id=2725**

■ *Rutherford Robotics can laser-cut the console for you* — **http://rutherford-robotics.com/laser.html**

■ *Parallax* — **www.parallax.com**

■ *Phil Davis* — ***phild2@charter.net***

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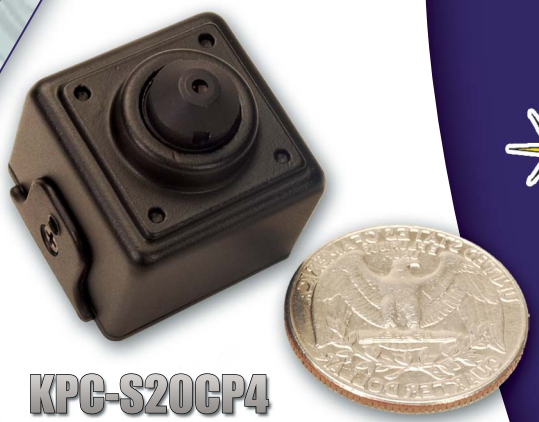

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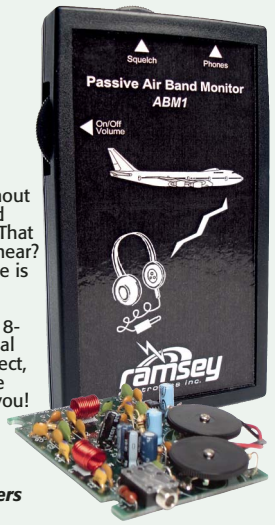

- ✔ **Monitors the entire aircraft band without tuning!**
- ✔ **Passive design, can be used on aircraft, no local oscillator, generates and creates no interference!**
- ✔ **Great for air shows**
- ✔ **Patented circuit and design!**

For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the plane you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. And unlike the FM capture effect, multiple aircraft signals will be heard simultaneously with the strongest one the loudest! And that means the aircraft closest to you, and the towers closest to you! All without any tuning or looking up frequencies! So, where would this come in handy?

1. ***At an air show! Just imagine listening to all the traffic as it happens***
2. ***Onboard aircraft to listen to that aircraft and associated control towers***
3. ***Private pilots to monitor ATIS and other field traffic during preflight activities (saves Hobbs time!)***
4. ***Commercial pilots to monitor ATIS and other field traffic as needed at their convenience***
5. ***General aircraft monitoring enthusiasts***

Wait, you can't use a radio receiver onboard aircraft because they contain a local oscillator that could generate interfering signals!

We have you covered on that one. The ABM1 has no local oscillator, it doesn't, can't, and won't generate any RF whatsoever! That's why our patent abstract is titled "Aircraft band radio receiver which does not radiate interfering signals". It doesn't get any plainer than that! Available as a through-hole hobby kit or a factory assembled & tested SMT version.

SPECIFICATIONS

Frequency Range:	118 MHz to 136 MHz
Receiver Type:	Patented Passive Detector
IF Frequencies:	None!
Receiver Sensitivity:	Less than 2 uV for detectable audio
Audio Output:	700mW, 8-24 ohms
Headphone Jack:	3.5mm stereo phone
External Antenna:	Headphone cord coupled
Power Requirement:	9VDC battery
Dimensions:	2.25" x 2.8" PC Board 2.5" x 4.6" x .9" Case
Weight:	4 oz. with battery

ABM1	**Passive Air Band Monitor Kit**	**$89.95**
ABM1WT	**Passive Air Band Monitor, Factory Assembled & Tested**	**$159.95**

Digital Tuned High Performance Aircraft Band Receiver

- ✔ **Rock solid dual conversion PLL receiver!**
- ✔ **Airport runway lighting controller output!**
- ✔ **4 user memory scanner banks, 20 freq's each**
- ✔ **Full band scanner with skip and skip/timer modes**
- ✔ **Internal front panel speaker**
- ✔ **External antenna input, speaker out, headphone out**
- ✔ **Stylish and shielded black metal enclosure**
- ✔ **Available as a hobby kit or factory assembled & tested**

Professional features at a hobbyist price! To begin with, we designed it with the latest technology, utilizing a rock stable synthesized PLL dual conversion receiver. We gave it superb image and adjacent channel rejection to allow you to lock onto the signals you want and not to be bothered by those you don't!

Once we got the RF portion designed we took a close look at the features desired in such a receiver. We gave it a neat 2x8 line LCD display to show you all the functions. Control of modes and setups is obtained through the front panel controls and confirmed on the LCD display. On/Off/Volume and Squelch controls are also provided on the front panel. We even gave it a front panel speaker in case you stack the lighting controller or something else on top of it! So far we've described the ultimate aircraft receiver that's not only the perfect field monitor for a hangar or airport manager's office, but for the serious enthusiast. Can it get any better than that? It sure can!

SPECIFICATIONS

Frequency Range:	117.975 MHz to 137.000 MHz 25kHz steps
Receiver Type:	Dual Conversion PLL
IF Frequencies:	10.7 MHz & 450 kHz
Receiver Sensitivity:	Less than 1 uV across the band
Image Rejection:	Greater than -80 dB
Adjacent Ch. Rejection:	Greater than -40dB
Scanner Banks:	4, 20 frequencies each
Audio Output:	1 watt, 8 ohms
Light Controller Output:	3 events, 5 events, 7 events output to controller
Power Requirement:	12VDC, 500mA
External Antenna:	BNC female, rear panel
Dimensions:	5.55"W x 6.45"D x 1.5" H

The top request we've had for a professional aircraft receiver was to embed automatic runway lighting control. Consider it done! The lighting controller follows the standard protocol for remote runway lighting. The pilot "keys" his microphone on the local CTAF channel for the specified number of times. All you need to do is set the receiver for the lighting control mode, then make sure the squelch is closed and will open on a suitably strong signal. Typically the number of "keys" or "events" according to the receiver control the lighting as follows: 3 events, 25% brightness; 5 events, 50% brightness; and 7 events, 100% brightness. The AR2's adjustable lighting timer sets turn-on duration to your needs. Includes the matching case and knob set and power supply. For the aviation professional that is not interested in building the receiver, the AR2 and the lighting controller are also available factory assembled and tested, ready to go. Just plug it in and you're all set.

AR2	**Synthesized Aircraft Receiver Kit With Case & AC Power Supply**	**$199.95**
AR2WT	**Factory Assembled & Tested AR2 Synthesized Aircraft Receiver**	**$269.95**
AR2L	**Plug-In Runway Lighting Controller Interface Kit With Case & AC Power Supply**	**$59.95**
AR2LWT	**Factory Assembled & Tested AR2L Runway Light Controller**	**$99.95**

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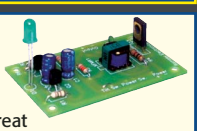
Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC

TS4 Tickle Stick Kit $12.95

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Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9 Super Snoop Amp Kit $9.95

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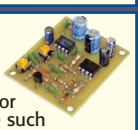

Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

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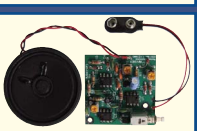
Our #1 Mini-Kit for 31 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Runs on 3-15 VDC.

BL1 LED Blinky Kit $7.95

Cricket Sensor



Senses temperature and changes the chirp accordingly. Can actually determine temp by chirps! Runs on 9VDC battery. Speaker included.

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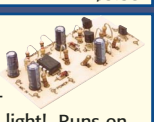

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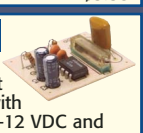

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to100 mA.

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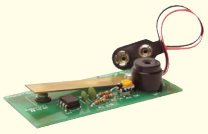

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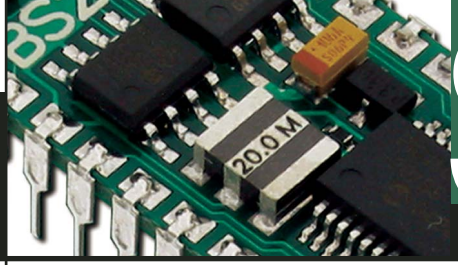


■ BY JON WILLIAMS

CONTROL VIRTUALLY ANYTHING ... VIRTUALLY

WHEN THE SX MICROCONTROLLER was developed, the core philosophy was to create a chip fast enough and clean enough that most specialized peripherals could be made "virtual," that is, created in code. And when SX/B was developed, the core philosophy was to create a compiler with such clean output that it could be used as a self-teaching guide for those wanting to learn assembly language. It may have taken me a while to catch on to the assembly stuff, but I think these promises have been met, and this month's project brings them together into a neat little device that just might save an old PC from the junk pile.

I think that most regular readers know I'm an actor (see **www.jonmcphalen.com**) which means I have a built-in interest in the movie business. And as much as I enjoy my work in front of the camera, I also love working with the myriad technical magicians behind the scenes. Because of this, a DVD purchase for me is usually based more on the "extras" material than the movie itself. When I was young, my parents had hoped that learning the secrets of Hollywood movie-making would dissuade me from my desire to act when, in fact, it had quite the opposite effect. A tour of Paramount Studios when I was a teenager sealed the deal for me and I've known all my life that some how, some way, I would be involved with movies and television.

The truth is that unless a movie is just horrible, I can completely lose myself in it and shut off that portion of my brain that knows how it was done. This goes for all movies — even those without people. One of those movies that caused me to have a, "I want to do that ..." reaction was *Team America*. Now, this kind of movie is not for everybody; Matt Stone and Trey Parker are well known for their bawdy, adult humor; the kind of stuff that *South Park* is made of — and made famous for.

And no, my reaction was not, "Hey, I want to do raunchy comedy!" It was, "Hey, I want to build a [small] animatronics control system." If you've seen *Team America*, you know that all of the characters are puppets — marionettes, in fact. What you may not know is that inside each of the puppet's heads were nine mini servos to control the facial movement. Imagine that: The puppet heads were a bit smaller than the size of a softball and yet they held nine servos! Servo control was done through a piece of specialized software, originated by Gilderfluke (the provider of the servo controllers) and heavily modified by the production crew for that enabled real-time control when required. In my opinion, the *Team America* puppets and their control demonstrate the tremendous skills of the craftspeople and engineers at The Chiodo Brothers CBFX unit.

So, I have had for some time now the desire to build a small animatronics control board that I could run from a PC — and I have finally got past a learning curve with the SX and done it. This month, I'm going to show you what I did. In the process, my goal is to show you how to combine virtual peripherals (VPs) when you have a project than needs more than one and, especially, when those VPs must run at different rates.

THE SPECS, PLEASE ...

As always, it's best to know where we're going before we start on the journey. The goal for this project was to have a PC-driven controller board that could manage eight digital outputs and eight standard servos. The digital outputs would be buffered by a ULN2803 so that they can drive lamps, relays, and other moderate-current devices. The servos will be the standard hobby type and will be refreshed every 20 milliseconds.

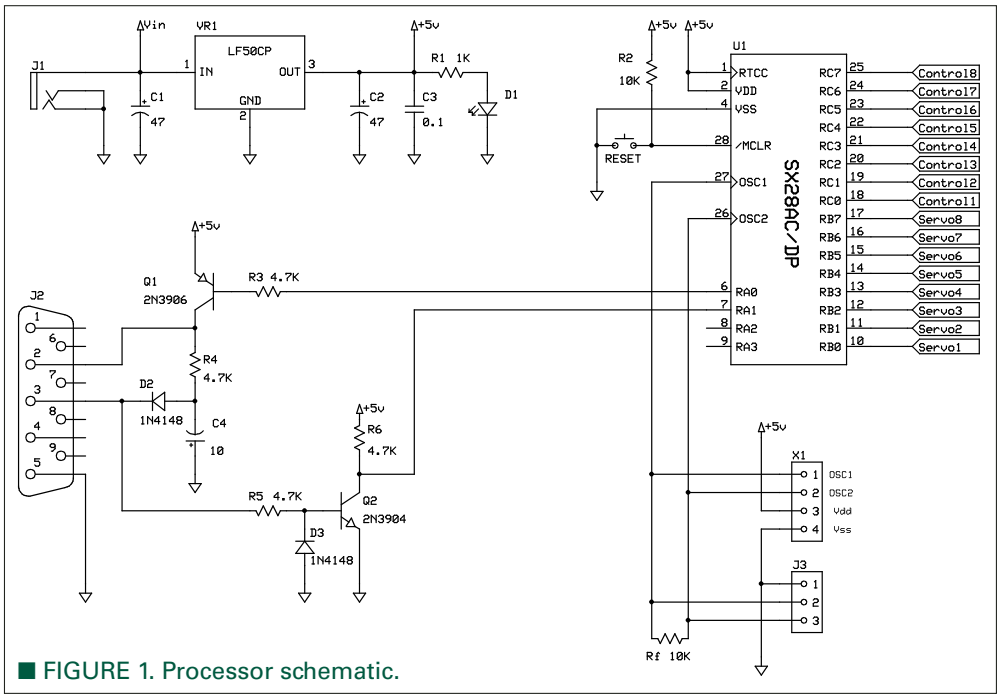
Based on these specifications, the hardware design is really simple, and that's a good thing. This board becomes somewhat generic and a change of code gives it a change of personality — always a useful trait in a microcontroller circuit. As you can see in Figures 1 and 2, we have a power supply, an SX28, a simple RS-232 interface, and the ULN — nothing to it. And due to the small parts count, the

project fits very comfortably on an ExpressPCB mini-board.

CRACKING THE CODE

The real challenge with this project is the code, probably the most sophisticated that I've presented in this column. I promise you, though, that after you've spent a bit of time with it, you will reach that comfort zone — something I hit within the last month or two — where mixing SX VPs is no longer a big mystery; it's simply a bit of work to do like anything else.

Having spent some time with other control protocols lately, specifically LANC and DMX512, I decided to take a page from those books and create a protocol for this project that uses a break in the control transmission as the synchronizing point. The idea is dirt simple: synchronization of the packet is achieved by leaving the receive line into the controller idle for at least two byte periods. After that, we will expect a nine byte packet; the first byte contains the state of the digital outputs and the eight bytes that follow are the position values for the servos. Figure 3 illustrates the control packet.



■ FIGURE 1. Processor schematic.

That all sounds pretty easy, right? It is, mostly, but things get a little tricky when we start to look deeper into the timing details. The packet structure and code on both ends is kept clean by using byte values for the servos, suggesting that we'd use a BS1-compatible, 10-microsecond resolution for servo position. This means, then, that in order to receive the packet while maintaining the servo positions we'd like to have an ISR rate that is 10 microseconds or a nice fraction thereof.

And there's the rub ... You see, we really need to put detail into the bit timing of the virtual UARTs so that we have reliable communications. I decided on a maximum data rate of 38.4K baud so that the level shifter circuitry could be removed and I could control this with a BS2. At 38.4K, the bit time is 26.042 microseconds. But remember, we need to sample the receive line at least four times per bit period so that means we need to set the ISR period to 6.51 microseconds.

You can see the problem: 6.51 microseconds is quite a long way from the 10 microsecond unit value we want for servo control, and doesn't divide evenly into it. What do we do? Well, if we divide the bit period by eight, we get 3.255 microseconds, and that multiplied by three is 9.766 microseconds, which is very close to the 10 we're looking for — we can live with that. This means, then, that to get the servo centered (at 1,500 microseconds) we will use a position value of 154 which actually gives us 1504 microseconds; I'd say that will work and we know that our serial data is going to be solid as we're actually sampling the receive line twice as frequently as we need to.

In review, we're going to set the ISR rate to 3.255 microseconds and have the serial routines divide that by eight for proper bit timing, and the servo routine will divide the ISR by three to derive its base timing of approximately 10 microseconds. The ISR does a couple other things, too; here is the list, in order of appearance:

- Process the delay timer (if running).
- Update the packet sync timer.
- Receive a serial byte.
- Transmit a serial byte.
- Refresh the servos.

Since most of the work for this project is done in the ISR, that's were we'll focus our discussion. Here we go ...

```
' ---------------------------------
  INTERRUPT NOPRESERVE 307_200
' ---------------------------------

Update_Delay_Timer:
  IF tix <> 0 THEN
    DEC tix
  ENDIF

Check_Sync_Timer:
  INC syncTimer
  IF syncTimer > SyncCount THEN
    armed = Yes
    syncTimer = 0
  ENDIF
```

The interrupt is declared with a rate of 307,200 times per second; this gives us a period of 3.255 microseconds. And as the SX/B code used in the interrupt doesn't use any

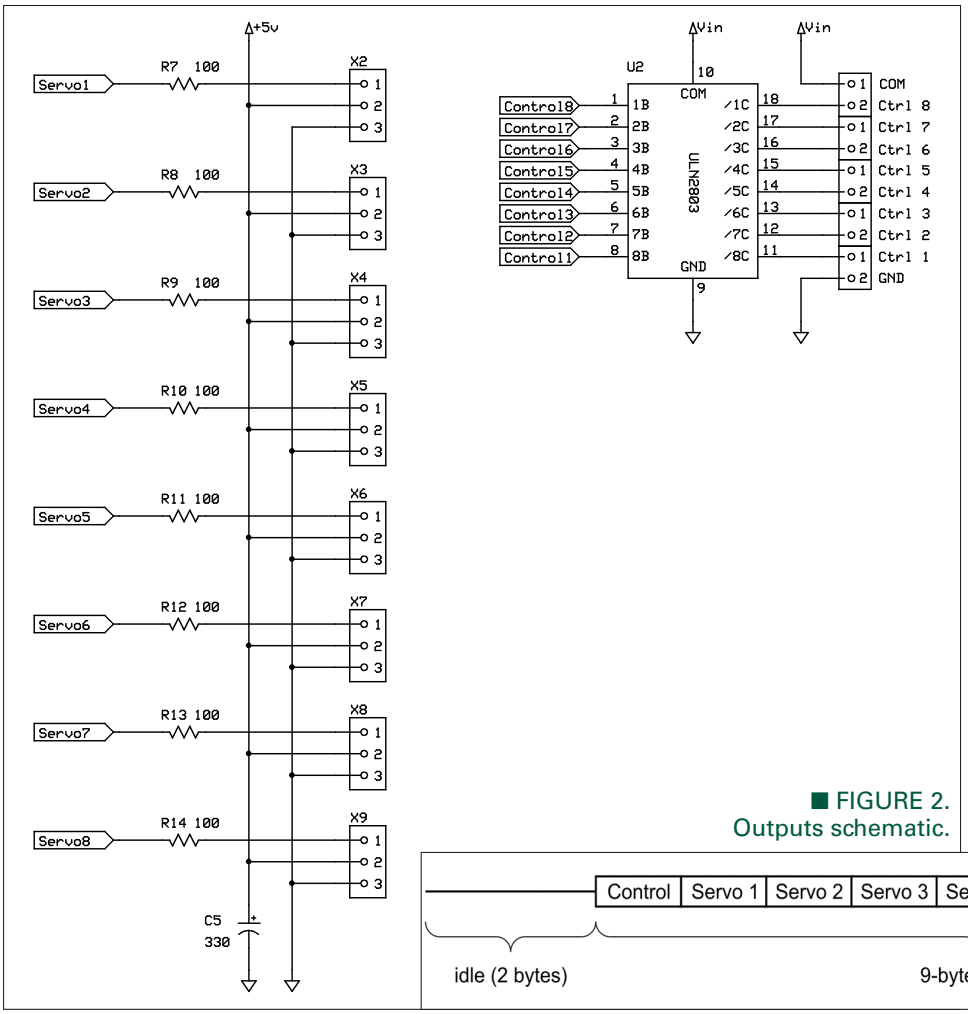
of the compiler's *__PARAMx* variables, we can use the **NOPRESERVE** keyword so that those variables — which aren't changed during the ISR — are not saved and restored; this just wastes time if we don't need it to happen.

The first VP encountered decrements the delay timer if it's running. Remember, **PAUSE** will not work properly with the ISR so we'll have to use a custom subroutine to handle that — we've done that in the last couple projects so I'm sure it's old hat by now.

Next up is the sync timer. It will be incremented each time through the ISR and if it goes past the required idle time bit count (20), a flag will be set that will allow the foreground process to receive serial data. What you'll see up ahead is that this flag and its control timer get cleared at the end of a received byte; this forces the program to ignore serial data for two byte periods after the last packet byte has been received.

And now for the receive UART. We've actually used this code a couple times before (see the serial seven-segment display project from January 05 for a detailed description). Briefly, the receive line is sampled until a start bit is detected. When this happens, the receive bit counter is loaded and the timer decremented. When the start bit timer (which is 1.5 bits long so that sampling starts in the middle of the first bit) expires, the line is sampled and the bit timer reloaded with one bit period. After all bits have been received, the *rxReady* flag bit is set and the *armed* flag and packet sync timer are reset.

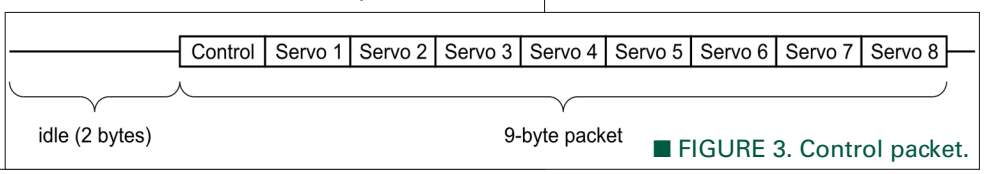
```
Receive:
  ASM
  JB    rxReady, RX_Done
  BANK  serial
  MOVB  C, RX
  TEST  rxCount
  JNZ   RX_Bit
  MOV   W, #9
  SC
  MOV   rxCount, W
  MOV   rxDivide, #Baud1x5

RX_Bit:
  DJNZ  rxDivide, RX_Done
  MOV   rxDivide, #Baud1x0
  DEC   rxCount
  SZ
  RR    rxByte
  JNZ   RX_Done
  SETB  rxReady
  CLRB  armed
  CLR   syncTimer

RX_Done:
  BANK  0
  ENDASM
```



■ FIGURE 2. Outputs schematic.

For those who might be new to SX/B, you can see how easily assembly code is integrated into the program through the **ASM..ENDASM** block. And to be honest, I didn't create this code; I "liberated" it from Al Williams' SX programming book *Exploring the SX Microcontroller* (available as a free PDF from Parallax). As good as SX/B is, there will be times when inserting some assembly code will be the best development choice — it's nice that SX/B makes it so easy. Another great source of assembly routines is Günther Daubach's excellent book *Programming the SX Microcontroller*. And don't forget James Newton's SX List (**www.sxlist.com**).

Next up is the transmit UART, something we haven't used in the past, but as with the receive UART, this was lifted right out of Al's book.



■ FIGURE 3. Control packet.

```
Transmit:
 ASM
   BANK   serial
   TEST   txCount
   JZ     TX_Done
   DEC    txDivide
   JNZ    TX_Done
   MOV    txDivide, #Baud1x0
   STC
   RR     txHi
   RR     txLo
   DEC    txCount
   MOVB   TX, txLo.6

TX_Done:
   BANK   0
   ENDASM
```

You can see that the transmit code is somewhat simpler that the receive code — the reason is that it's not waiting on anything, it's just doing something. To transmit a byte, we'll load the byte to send into *txHi* (the output buffer) and set the bit count, *txCount*, to 10; we have one start bit, eight data bits, and one stop bit. Of course, we don't want to try to send a byte when we're in the middle of another, so we'll check to make sure *txCount* is zero before sending a new byte.

After enabling the transmitter, a start bit is placed on the line and then the bits are sent out, at the specified baud rate, LSB to MSB. You can see the **RR** (rotate right) instructions in the code that shift the bits of the transmitted byte out one at a time. Note that the **STC** (set carry) instruction precedes the buffer rotation; what this does is pad the end of the shifted data byte with 1s so that we have a valid stop bit. If, for example, we wanted to have two stop bits, the only change we'd need to make is to set *txCount* to 11.

What may not be apparent is that the program can receive and transmit bytes at the same time because our circuit uses separate RX and TX pins. Yes, you can use the same pin, but you'll have to add a bit of check logic in the **TX_BYTE** subroutine to make sure that we're not in the middle of receiving a byte when we want to transmit one — other than the RX/TX pin definition(s), the ISR code remains the same.

Okay, now for the really fun bit: the code that handles the servo control. First things first: We have to divide the ISR period by three to get the base servo timing. It's easier than you think:

```
Test_Servo_Tix:
   ASM
   BANK   svoData
   INC    svoTix
   CJB    svoTix, #3, ISR_Exit
   CLR    svoTix
```

All we have to do is count up to three and execute the rest of the servo management code when we get there, otherwise we jump to the exit point of the ISR. Let me share a secret with you ... this bit of code started as high-level SX/B that looked like this:

```
Test_Servo_Tix:
   INC svoTix
   IF svoTix < 3 THEN ISR_Exit
   svoTix = 0
```

So why bother converting to assembly? Because I want to learn and get comfortable with assembly, and the best way is by exploring good examples — starting with simple stuff. If you look at the list file output of one of your programs (press Ctrl-L in the SX-Key IDE), you will see how your SX/B code is translated into assembly. In fact, the entire servo processing section started that way; I took the assembly output from the compiler, trimmed the few extra bits (that the compiler uses for safety), and used it in the program. Doing this forced me to crack open the SX book and look up instructions so that I could really understand what's going on. There will come a time when we have really critical timing requirements and using assembly is going to be the way to get there. The reason SX/B provides such a clean output is so that folks like us can learn from it, and for me that promise is holding true.

Okay, back to the servo stuff ...

Here's how the servo processing works. At the expiration of a 20 millisecond timer, the first servo, *svoFrame*, is started and the pulse timer, *svoTimer*, is loaded with the servo value. On subsequent passes through the code, the servo pulse timer is decremented. When that timer expires, the next servo is started and the servo timer value is reset to the appropriate value. After the eighth servo is finished, nothing happens until the 20 millisecond frame timer expires and the process starts again. Figure 4 shows what the servo outputs look like in action and in relationship to the frame timer. As you can see, only one output is on at a time — this means we only need one active servo timer, so this significantly simplifies the program.

Okay, here's the bit that handles the frame timer; in this code, you can see that when it expires the first servo port is enabled and the servo timer is loaded with the Servo 1 timing value.

```
Check_Frame_Timer:
   CJNE   svoFrame_LSB, #0, Update_Frame_Timer
   CJNE   svoFrame_MSB, #0, Update_Frame_Timer
   MOV    svoFrame_LSB, #2048 & 255
   MOV    svoFrame_MSB, #2048 >> 8
   MOV    svoPin, #%00000001
   CLR    svoIdx
   MOV    FSR, #pos
   MOV    svoTimer, IND
   JMP    Refesh_Servo_Outs

Update_Frame_Timer:
   SUB    svoFrame_LSB, #1
   SUBB   svoFrame_MSB, /C
```

Two things of note: 1) We use a value of 2048 for the frame as our effective rate is 9.765 microseconds, and 2) By devoting the eight contiguous bits for the servos, the control and updating of outputs is made very simple. Here's how it works:

```
Check_Servo_Timer:
  TEST   svoPin
  SNZ
  JMP    ISR_Exit
  DEC    svoTimer
  SZ
  JMP    ISR_Exit

Reload_Servo_Timer:
  INC    svoIdx
  CLRB   svoidx.3
  MOV    W, #pos
  ADD    W, svoIdx
  MOV    FSR, W
  MOV    svoTimer, IND

Select_Next_Servo:
  CLC
  RL     svoPin

Refesh_Servo_Outs:
  MOV    ServoCtrl, svoPin

ISR_Exit:
  BANK 0
  ENDASM
  RETURNINT
```

The **TEST** instruction lets us check a variable for zero — so we look at the active servo pin control value, *svoPin*. If no servos are running, then it will be zero and the routine will exit. Otherwise, we can decrement the timer for the servo that is presently running.

When the timer expires, we increment the servo index pointer (keeping it in the range 0..7) and reload the timer for the newly-selected servo. By doing a left shift (**RL**) on the servo control value, the next servo is activated when we write that value to the physical control port (RB, in this case). It is necessary to clear the carry bit before the **RL** instruction so that previous servo ports get turned off.

Whew ... we have just done a whole lot of work in the ISR. The payoff? Look how simple the foreground program is:

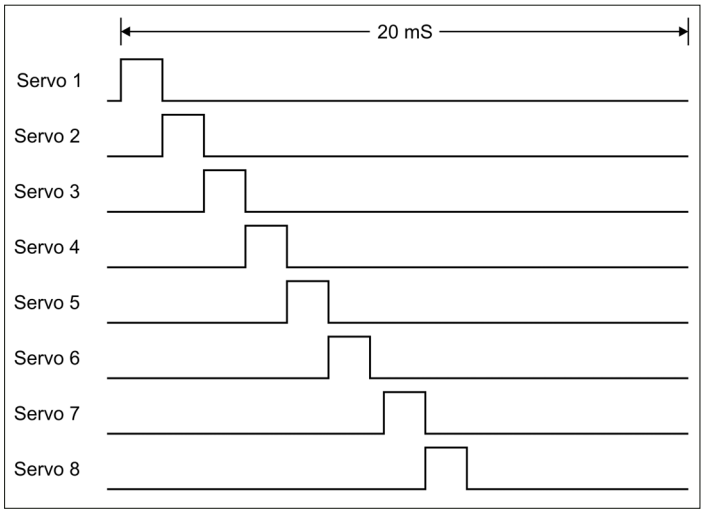
```
Start:
  Outs = %00000000
  FOR idx = 0 TO 7
    pos(idx) = 154
  NEXT

  TX = 1
  DELAY_MS 2

Main:
  IF armed = No THEN Main
  Outs = RX_BYTE

  FOR idx = 0 TO 7
    IF armed = Yes THEN EXIT
    pos(idx) = RX_BYTE
  NEXT

  GOTO Main
```

At ***Start***, we clear the outputs and center the servos, set the TX pin and let it idle so that the receiver doesn't get any junk, and then wait for bytes to come in. Again, we don't want to receive anything unless there has been a valid idle period. When this has happened, the *armed* bit will be set. Note that the servo position values are received in a loop with a recheck of the *armed* flag between each; what this does is allow the program to escape from that loop if the packet transmission gets interrupted.

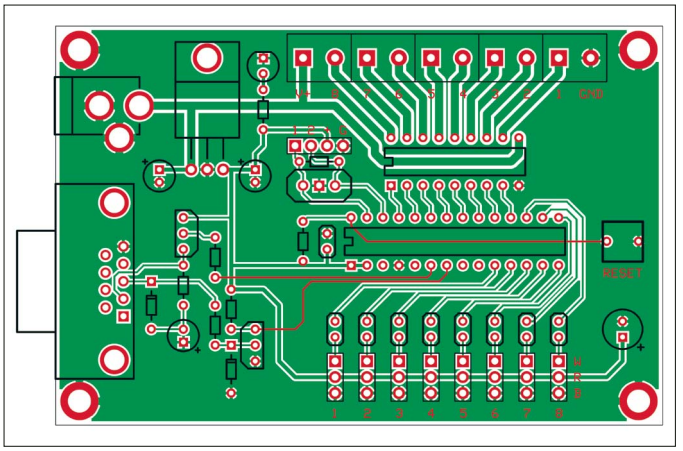
CONSTRUCTION NOTES

As with the past few projects, I used ExpressSCH for the schematic and created the board with its companion, ExpressPCB. Please, please, please ... don't think you can do boards manually anymore. ExpressSCH will let

■ FIGURE 4. Servo pulse outputs.



■ FIGURE 5. Animatronics controller PCB.



you check for gross errors and ExpressPCB will link to your schematic to show you what connects to what. This is a huge timesaver and way to prevent headaches. A friend of my recently skipped the link step and created a board manually — and then ended up sorry for it as he had problems with that board.

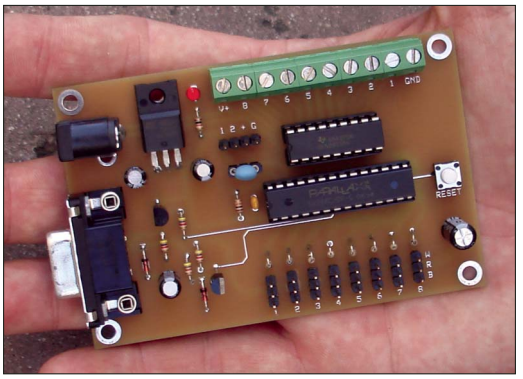
One of the latest features of ExpressPCB is the ability to add a flooded plane to the top or bottom layer of the board. I decided to use this for ground instead of running traces. When you make your own boards, it's usually best to lay out the components and other traces first, then add in the flooded plane. To connect a component to my ground plane, I had to right-click on the pad, then select *Bottom Layer Pad Shape*, then select the connection type; I used *Thermal Pad to Filled Plane*. For vias that are not soldered, you could select a solid connection to the plane.

As Figure 5 shows, the plane goes everywhere except where there are traces and pads and where you explicitly tell it not to be (I removed a couple stranded islands). When you build the board, you need to be very careful about solder bridges from a pad to the plane — it's easy with no solder-mask ... I found out the hard way. On my initial test of the board, I found that control output 1 didn't work; with a loupe I discovered a hair-thin solder bridge from RC.0 to the ground plane. Thankfully, the SX28 is a tough dude, and removing the solder bridge fixed the problem; the pin did not seem damaged. The lesson here is to use a clean iron with a sharp tip, and lift it straight up instead of dragging it away from the pad.

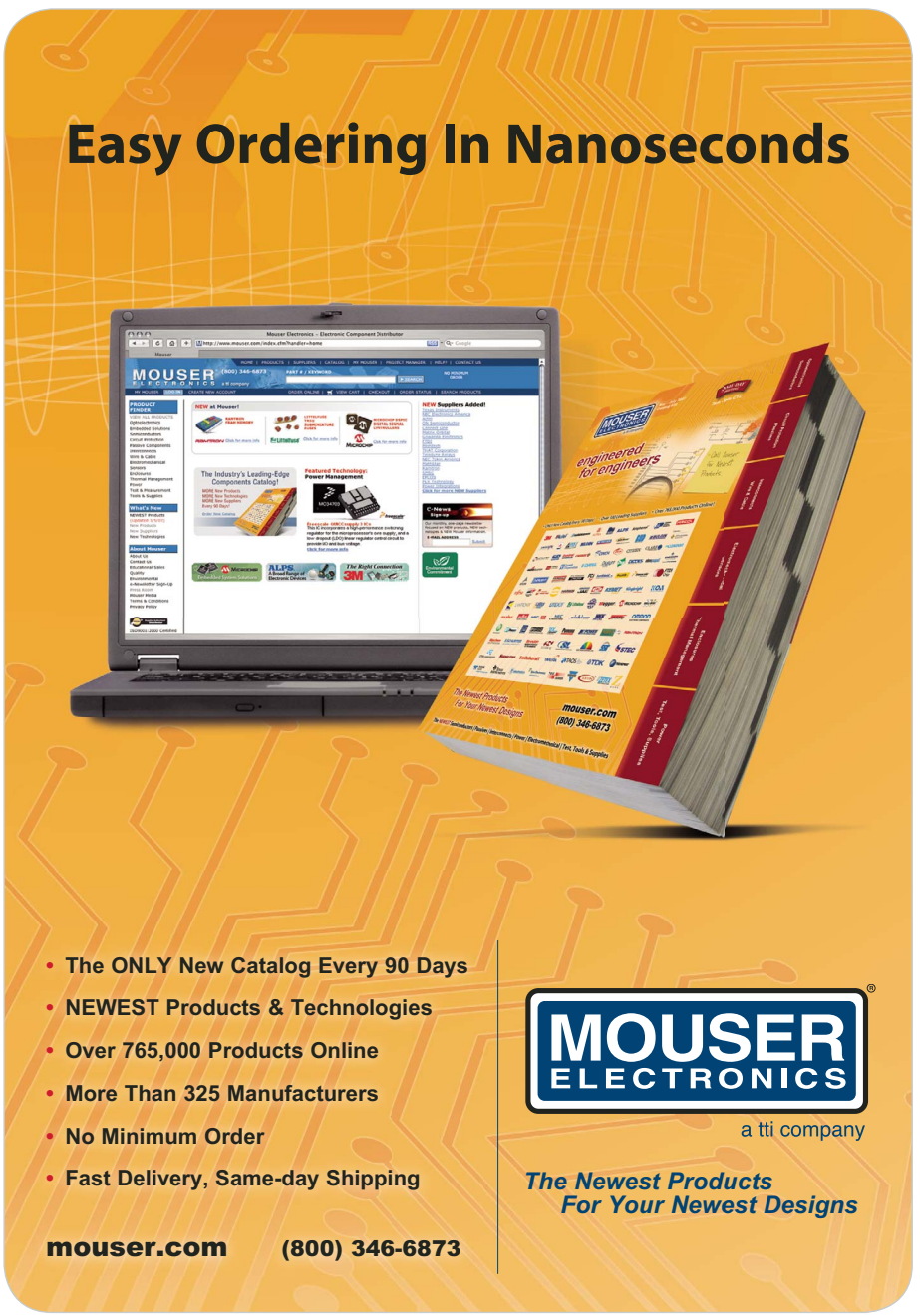
Figure 6 shows the completed controller — as you can see, I now have animatronics control in the palm of my hand! The photo shows that I stood resistors R7-R14 on end. If you're comfortable with SMD soldering (I'm not, yet), you can probably fit SMD resistors between the top pads.

TESTING THE ANIMATRONICS CONTROLLER

To test the unit, I wrote a simple Visual Basic program, as shown in the source code included in the



■ FIGURE 6. Animatronics controller.



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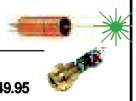

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STACKA - 12 stages at 12 kv each for mini-multipliers.....$24.95

High Voltage Transformers

Includes circuit schematics on how to use.

28K089 - 7kv 10ma 30 khz 9-14v 1"cube....$19.95
28K074 - 4kv 15ma 30 khz 9-14v 1"cube....$17.95
28K077 - 2kv 10ma 30 khz 7-9v .7x1.25.....$9.95
CD25B - 20 kv trigger pulse 1 x 1.25.....$16.95
CD45 - 40 kv trigger pulse 1.25 x 1.25.....$18.95
TRAN1035 - 10 kv 35 ma bal output.....$39.95
FLYLABURN - 10 kv 60 ma end grd.....$49.95
FLYEXP - 7 misc flybacks.....$34.95
FLYPVM400HP - High power flyback.....$34.95

High Volt/Freq Modules

12 vdc with instructions on how to use.
MINIMAX2 - 2kv 10 ma 50 khz $17.95
MINIMAX3 - 3kv 10 ma 35 khz $19.95
MINIMAX7 - 7kv 10 ma 35 khz $34.95
SS01S - 1 to 7kvac for ozone $24.95
GRADRIV10 - 7.5 kv 15 ma 35 khz adj ... $79.50
PVM400 - 20kv 25ma 115vac input $189.95

High Volt DC Modules

12 vdc with instructions on how to use.
PBK40 - 10 kv 100ua 9 vdc in $34.95
CHARGE10 - 10kv 2.5 ma $59.95
TRIG10 - 20 kv trigger/shock pulses $54.95
SS016S - +20kv 100ua $29.95
SS010S - Minus 20kv for neg ions $24.95
HV250 - 25,000 volt power supply.....$39.95

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Includes plans for a TESLA coil. Parallel for 60&120ma.

4KV/.03 - 4kv 30ma 60hz floating output $59.95
6KV/.02 - 6.5kv 20ma 60hz float output $59.95
9KV/.03 - 9kv 30ma 60hz midgrd output $79.95
12KV/.03 - 12kv 30ma 60hz midgrd output $109.95
15KV/.03 - 15kv 30ma 60hz midgrd output $139.95
14.4KV/.5A - 14.4kv .5amp pole pig ..... POR

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SPARK05 - Single gap 1/4" tungsten $49.95
TUNG141B - 1/4" x1" pair electrodes with holders tungsten $14.95
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TO12 - 12 x 3" Spun Aluminum Toroid.. $79.95
TO24 - 24 x 6" Spun Aluminum Toroid..$399.95
TO30 - 30 x 7"" Spun Aluminum Toroid..$525.95

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Orders: 800-221-1705 **Info:** 603- 673-6493 **Fax:** 603-672-5406
Email: riannini@metro2000.net

PARTS LIST

Item	Description	Source/Part No.
C1, C2	47 µF	647-UVR1V470MDD
C3	0.1 µF	80-C315C104M5U
C4	10 µF	647-UVR1E100MDD
C5	330 µF	647-UVR1A331MED
D1	LED	M859-LTL-4222N
D2, D3	1N4148	512-1N4148
J1	2.1 mm barrel	806-KLDX-0202-A
J2	DB9-F, R/A	571-5747844-4
J3	Pin socket	506-510-AG91D
PB1	N.O. button	612-TL59F160Q
Q1	2N3906	610-2N3906
Q2	2N3904	610-2N3904
R1	1K	299-1K-RC
R2, Rf	10K	299-10K-RC
R3-R6	4.7K	299-4.7K-RC
R7-R14	100Ω	299-100-RC
RES	50 MHz	Parallax; 250-05060
TB1-TB5	Two-pos term	571-2828362
U1	SX28AC/DP	Parallax; SX28AC/DP
U2	ULN2803	595-ULN2803AN
VR1	LF50CP	511-LF50CP
X1-X9	Pin header	517-6111TG

All parts are from Mouser unless noted otherwise.

download file on the *Nuts & Volts* website (**www.nutsvolts.com**). It's very simple: Once a serial port has been selected and opened, a timer is started that sends the packet every 20 milliseconds. Sending it more frequently makes no sense because the servo framing timer is 20 milliseconds. It won't hurt, of course, and you can cause the control outputs to change at the packet transmission rate — so long as the transmission rate is just over 11 byte periods long.

I think that 20 milliseconds is probably a useful value for packet transmission timing considering the mechanical elements that are to be controlled with the board (servos take time to move). This will work with data rates down to 9600 baud (which you might want to use if the RS-232 cable is long). Do keep in mind that the little transistor level-shifter circuit is not true RS-232; the TX level out is only 5V. If you need a long transmission line, you can replace these components with a MAX232 or similar device. RA.2 and RA.3 are available, so they could be used for hardware flow control on a derivative project, if required.

So, here's an opportunity to save an old PC from the scrap heap. It doesn't take a lot of resources to send serial data, so what I'm going to do is reformat an old laptop and devote it to animatronics control for Halloween and Christmas. For me, the next big question is the PC development language; I tend to default to VB because I have a lot of practice with it, but I would like to work with others who run different operating systems (Mac, Linux, etc.). So, I'm looking for a cross-platform development tool with which I can develop the same comfort as I have with VB. Java seems to be the leading contender, but if you have another suggestion, I'm open to it.

Okay, that's about it. Be sure to study the full listing and don't be concerned if it doesn't make sense right away. When it does, a big smile will cross your face and you'll be off to other things. Not too long ago, I helped a customer in the Parallax SX forum to mix VPs for "background" serial I/O and Sony SIRCS decoding, and at the moment I'm working on a serial-controlled lamp dimmer. Once you're used to mixing VPs, you'll find that you can control virtually anything — virtually! Well, until next time, Happy Stamping! **NV**

JON WILLIAMS
jwilliams@efx-tek.com

RESOURCES

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www.sxlist.com

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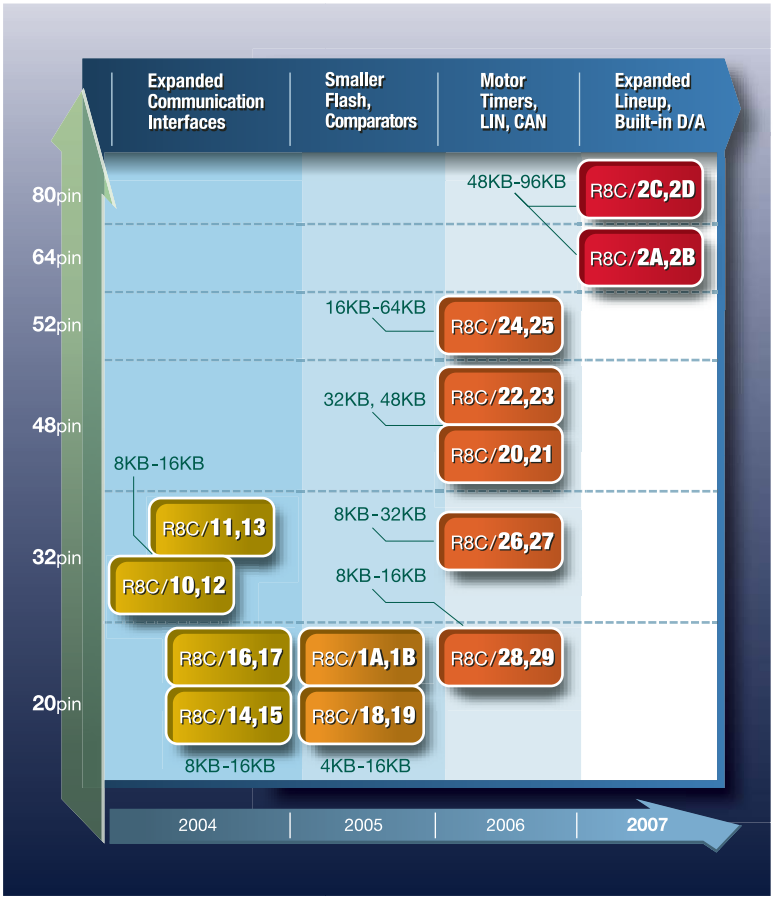
introduces the R8C/Tiny Series of microcontrollers. Its powerful 16-bit CPU core running at 20MHz provides the performance never imagined in 8-bit MCUs. R8C/Tiny MCUs high level of integration and peripheral set will enhance your application's functionality while reducing the overall system cost.

R8C/Tiny Product Roadmap



HOT Products | **R8C/25**

R8C/Tiny CPU	Program Flash (16KB - 64KB)	RAM (1KB - 3KB)
Oscillation Circuit Main Clock (20MHz Max.)	Data Flash (2KB)	Power-On Reset Circuit
On-chip Oscillators (40MHz, 125KHz)	Low Voltage Detect Circuit	Protect Register
Oscillation Circuit Sub Clock (32KHz Clock)	Enhanced WDT	16-bit motor control Timer (2)
RTC	External Oscillation Stop Detection	8-bit Timer (3)
Serial I/O Clock Sync./ UART (2ch)	SSU/I2C	A-D Converter (10-bit x 12ch)
44 GPIO	Hardware LIN	On-Chip Debug

Package: 52pin LQFP (10mm x 10mm, 0.65mm pitch)

Top Reasons To Select R8C/Tiny

- **High-Performance**
  - 16-bit CPU runs at 20MHz, executing instructions in as fast as 50nsec.
- **Scalable**
  - Same core, same peripherals allows easy portability from 20 to 80pins
- **High-Integration**
  - Includes 40MHz on-chip oscillator, data flash, power-on reset circuits, several 8- and 16-bit timers, up to 20 channels of A/D, D/A, LIN, CAN and more
- **Reliable**
  - Oscillator stop detection circuits, access control of system registers
  - Watchdog timer with on-chip oscillator, programmable low-voltage detect circuit
- **World-class Development Environment**
  - Complete software and hardware tools for short development cycle
  - *Free 64KB software tool chain*

*Source:Gartner Dataquest (April 2006) "2005 Worldwide Microcontroller Vendor Revenue" GJ06333

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ **A current limiting mystery.**
- ✓ **Happy fish.**
- ✓ **A game show quizzer.**
- ✓ **Vespa flywheels.**

■ WITH RUSSELL KINCAID

I was saddened to hear of T.J. Byer's death; I have been in awe of his range of knowledge and enjoyed his column. I am honored to be asked to continue the column and hope to be as interesting as he was. My experience has been as an analog design engineer, although, I have recently discovered microprocessors and will use one when applicable and simple enough that I can do it. I will no doubt make some mistakes, but there are certainly readers that can set me straight. Feedback is welcome. — *Russ Kincaid*

Send all questions and comments to:
Q&A@nutsvolts.com

A Short Biography of Russell Kincaid:

I became interested in radio while in high school. I saw an ad in Popular Science for a battery-less, tube-less radio and bought a crystal radio kit. A neighbor, who was a college student, helped me build a short wave radio and I was hooked. I got a book from the library and built some radios of my own. I talked my parents into sending me to the Commercial Radio Institute, in Baltimore, Maryland, but was drafted and spent a year teaching basic electronics at the Infantry School, Fort Benning, Georgia. I took advantage of the GI Bill and went to Rensselaer Polytechnic Institute in Troy, New York, getting an MEE degree. I worked for 22+ years as an analog design engineer at Sanders Associates and subsequent assigns, and seven years as Manager of hybrid electronics for Sprague Electric. I told myself that I would never retire, but the demand for analog engineers is greatly diminished, and I found myself out of work at 59 years old, so I retired. I have been retired for 18 years and will never get to the bottom of my to-do list.

CAUSE OF CURRENT LIMIT?

Q I am using a coil to generate a magnetic field and in turn, control the torque in a clutch. The current control uses an H-bridge to apply a PWM duty cycle. My coil resistance = 1.3 ohms, the inductance = 4.1 mH and I expected to move more than 10A through the coil at a frequency of 5 kHz at 15 VDC. For some reason, I can not get more than 8A to flow. I wonder if there's some power consumption in the PWM switching semi-conductors?

Where can I measure the power consumption in the PWM circuitry? It seems to me the junction resistance is just 1.3 ohms and I am supposed to be able to generate a current 15/1.3 = 11.5A.

— WR Hwang

A The resistance that is limiting you to eight amps is: R = 15/8 = 1.9 ohms. The coil is 1.3 ohms which leaves 0.6 ohms in the H-bridge, which is perfectly reasonable. You need a better H-bridge or more supply voltage.

BANDSTOP FILTER

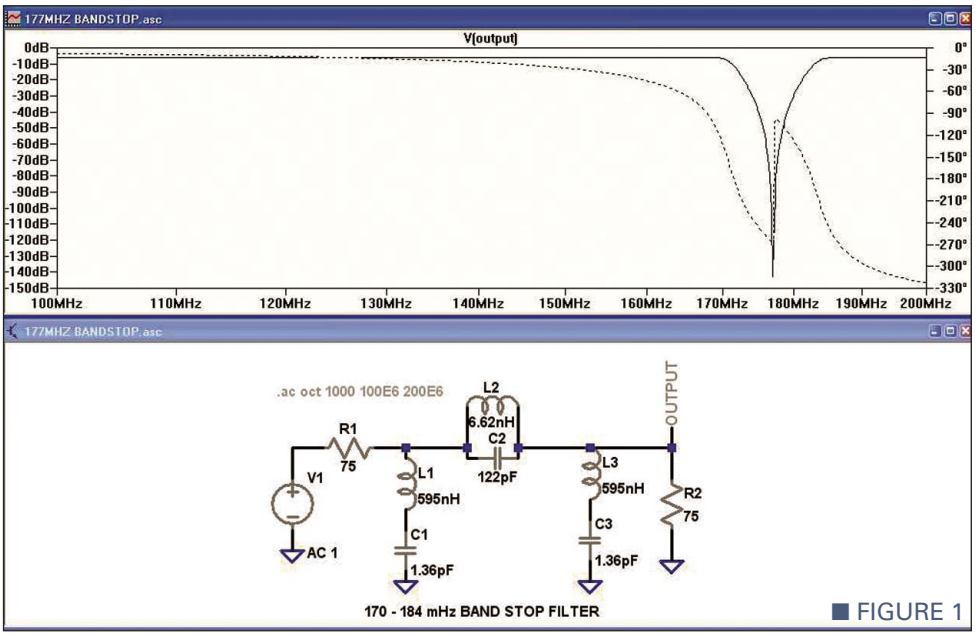
Q I need a reject filter for off-air Channel 7. One of the area DTV signals is on 9, and I have a severe intermod problem when I amplify it enough to be useful.

I haven't been able to find a manufacturer — or individual — with a sweep setup that sells or will build a 75 ohm, 170-184 MHz reject filter.

— David Schoepf, Marianna, FL

A I designed a three-pole bandstop filter to see what it looked like: check out Figure 1. The design is for perfect inductors; the real thing won't be as good. Note the 1.36 pF capacitors; the stray capacitance will be significant and such a small value can be made by twisting two enameled wires together. Cut the wires to trim the value. You will need a sweep generator to tune the filter. This equation can be used to wind the inductors: L = N^2(RADIUS/2(9*RADIUS + 10*LENGTH)). Dimensions are in inches, inductance is in micro-

henries. Layout is critical in high frequency filters; in particular, the coils should be at right angles to each other. I designed this filter using Philip R. Geffe's book *Simplified Modern Filter Design*, John F. Rider Publisher, 1963.



■ FIGURE 1

FISH TANK TACHOMETER

Q Could you please suggest a circuit and component design to monitor the flow of water through a pipe? I envision a paddle wheel with possibly two small magnets on opposite sides (to balance the spinner) and with a pickup coil outside the housing to sense the impulses as it rotates. I am capable of making up the mechanics of the unit but not capable of designing the electronics.

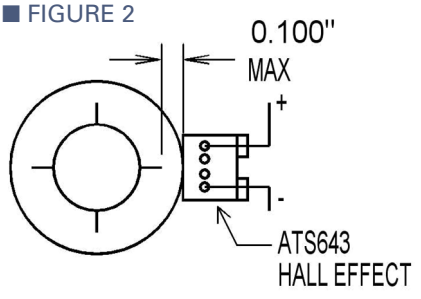
I have three filters on a fish pond in parallel with a common outlet. When one needs cleaning, there is no way to tell which one has slowed. The paddle would just dip a little into the stream so as to not slow the output and be sealed in each unit. The frequency might be displayed on a small screen. The speed indicated would simply be compared to each filter to tell which one needed cleaning when it was clean or fouled.

Thank you for your help.

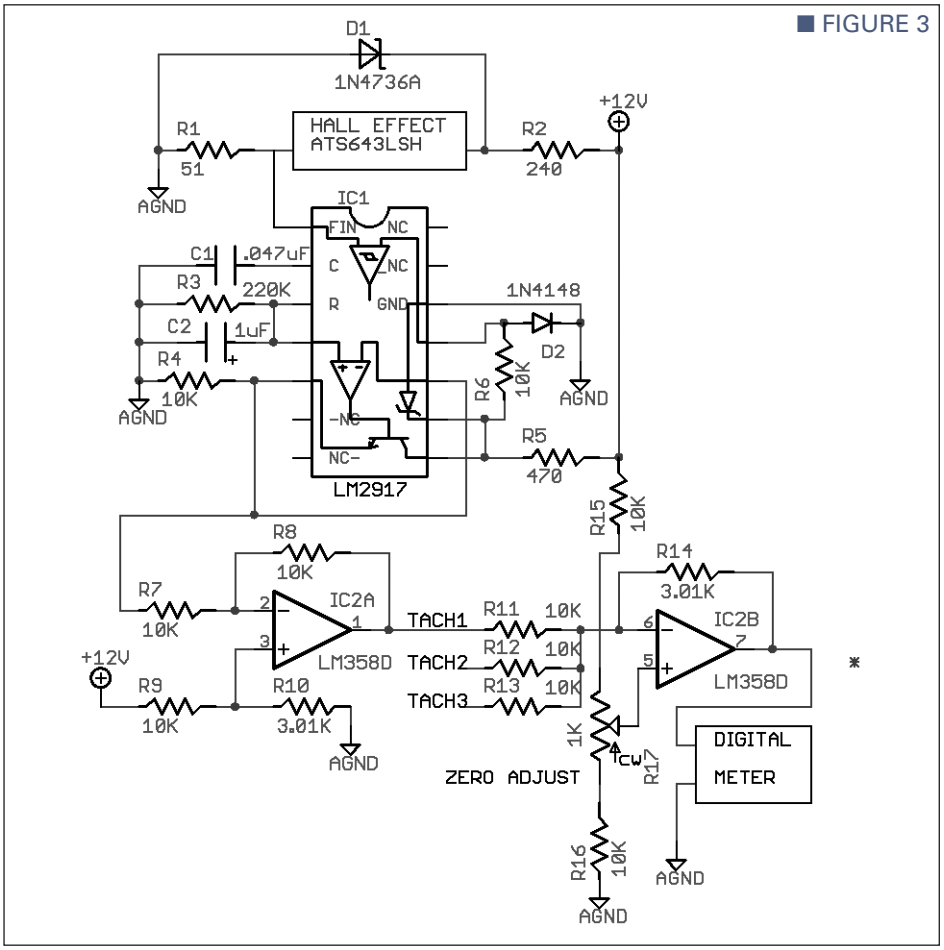
— Charles Forman

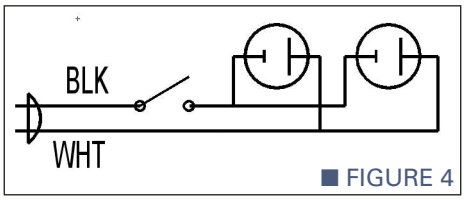
A I will leave the mechanics up to you. I found this Hall effect IC, made by Allegro Microsystems; the datasheet is at: **www.allegromicro.com/data file/0643.pdf**. It has the magnet built in so your measuring vanes only need to be made of ferrous material. The enclosure should be brass, aluminum, or non-magnetic stainless steel. Mount the Hall effect switch on the outside and connect it to a frequency-to-voltage converter. The maximum spacing between vane and IC is 0.1 inch, as shown in Figure 2. You can use a digital voltmeter to read the voltage and calibrate it to the

■ FIGURE 2



■ FIGURE 3





■ FIGURE 4

flow rate, if you wish. In the circuit in Figure 3, I added the three outputs and divided by three so you only need one voltmeter. When the indication is slowed, you can switch the meter to the individual outputs to see which one has slowed.

I don't know how fast the paddle wheel will rotate in this system; I assumed 300 RPM maximum in this design, but the equations to change the maximum RPM are:

C1 = 21.3/Fmax in microfarads and,
R1 = 6.26*Voutmax in Kohms.

The Hall effect IC has a current output, 6 mA minimum and 16 mA maximum. It switches between those values as the vanes rotate. I used a 1N4148 diode to bias one input so that 6 mA times 51 ohms will be less than the diode drop for a low input; 16 mA times 51 ohms is more than the diode drop for a high input. You could connect the voltmeter to the LM2917 output, but I wanted to add the three tach signals and the summer inverts the signal, so I needed an inverter in front of the summer. The inverter also converts the 0-to-6 volt signal from the LM2917 to a 6-to-0 volts signal into the summer.

FLYWHEEL RE-MAGNETIZER

Q I built a re-magnetizer for Vespa P series flywheels that produces a strong field at all six solenoid core ends, or shoes, as I call them. But, the rig doesn't work on the flywheels. I copied loosely a picture of a factory machine. The Vespa flywheels are about six inches ID. Six 2 x 1.5 inch magnet faces of alternate polarity are exposed within the inside diameter. The re-magnetizer has six solenoids wound with five wraps of 12 gauge stranded copper wire on 5/8 x 8 inch mild steel bolts that end in one inch square angle iron shoes fitting inside the flywheel diameter to complete the flux circuits on the business end of the re-magnetizer. All solenoids (electromagnets) are in parallel with about half an ohm resistance overall; 160 amps for two seconds warmed the coils but a little. Assuming polarities are correct, what is likely wrong with my contraption? Are the solenoid shoes too small and too loosely fitted against the magnet faces? Do I need a bolt through the flywheel center connecting to the re-magnetizer bottom, thus completing the flux circuit in another way? The picture of the factory machine hinted at something like this.

— Melvin Schallot

A Any air gap will greatly reduce the magnetic field; the fit should be tight. I would connect the coils in series because you don't know how the current divides when in parallel. You will need 88 volts to drive 27 amps through the six series coils. If you charge up a 1,000 µF, 100 volt, can type, high ripple electrolytic capacitor and discharge it through the coils, that should work; although bigger is better. If all the coils are wound identically, then you mount them around the circle; the magnetic fields will cancel unless you reverse every other one. That may be the real problem. You only have to reach a peak of magnetic flux in order to re-magnetize. Time is not a factor, as far as I know.

SAWDUST VACUUM

Q I use a table saw with a shop vacuum attached. It would be more convenient if the vacuum would come on automatically whenever I start the table saw. I think a current/voltage sensing system may have already been published. However, would you please recommend such a system?

Thank you very much for any help you can give.

— Frank Lemon

A I assume the shop vacuum and saw both run on 115 VAC, so just connect the saw motor and shop vac in parallel. If you don't want to mess with the saw switch, buy a switch box and switch at the local hardware store, and while you are there, get an outlet box and outlets. You can wire it up per Figure 4 and plug both the saw and vacuum into the outlet box.

GAME SHOW LOGIC

Q I'm looking for assistance in designing a hobby circuit to use as a game show quizzer for our church youth. I've made several quiz boxes over the years using SCRs as the trigger and latch device per the schematic I found in the Feb. 1977 issue of *Popular Electronics* magazine. I need to update the design to show which contestant came in first, second, third, and fourth in a match with four teams of five contestants per team (20 total contestants). I'd also like to select between individual mode (where each contestant competes against all others) and team mode (where the fastest contestant on a team locks out the rest of his team).

Each contestant will hold a normally open push button to depress when they think they can answer the question. This sounds a buzzer (telling the quizmaster to stop reading the question), lights their signaling light on a remote team light box, as well as lights in front of the timekeeper official (color of light or blink rate identifies if they were the first, second, third, or fourth), and starts a digital timer. The circuit should not have any ties (response rate of 0.1 millisecond or faster).

It also needs immunity to static electricity since it will used be in a carpeted room during the winter with lots of spectators walking around. I can accept a hardware or software solution. I have some experience

with the Parallax BS2sx OEM module, but it has a limited number of I/O pins and barely meets the response rate requirement. Any help would be appreciated.

— James Good

A The circuit diagram (see Figure 5) is for one player. When a player presses his button, his light lights if he has been faster than the other players. Once the light is on, all other players are locked out at that level. The game master has the reset button to reset all the lights. Here is the detail of how it works:

Initially Q of IC1A is low causing Q3 output to be in the high impedance state. Enable line #1 is high, being pulled up by R1. When a player pushes his button, the output of IC6B goes low causing IC5B output to go high which, in conjunction with enable line #1 being high, causes IC5A output to go low and set Q of IC1A high. At the same time, Q3 pulls line #1 low, locking out all other players on the bus. When not-Q goes low, the output of Q4 goes high, enabling line #2. Similar logic applies to second, third, and fourth place. There may be a problem in driving the LED with the Q output; a buffer/driver may be needed.

If the mode switch is in the team position, the player push button works as long as the lockout bus is low. When any person on the team lights a light, one of the inputs to IC4A goes low, making its output high. The output of the inverter, IC6A, goes low allowing the lockout bus to go high. The buzzer bus is active when low.

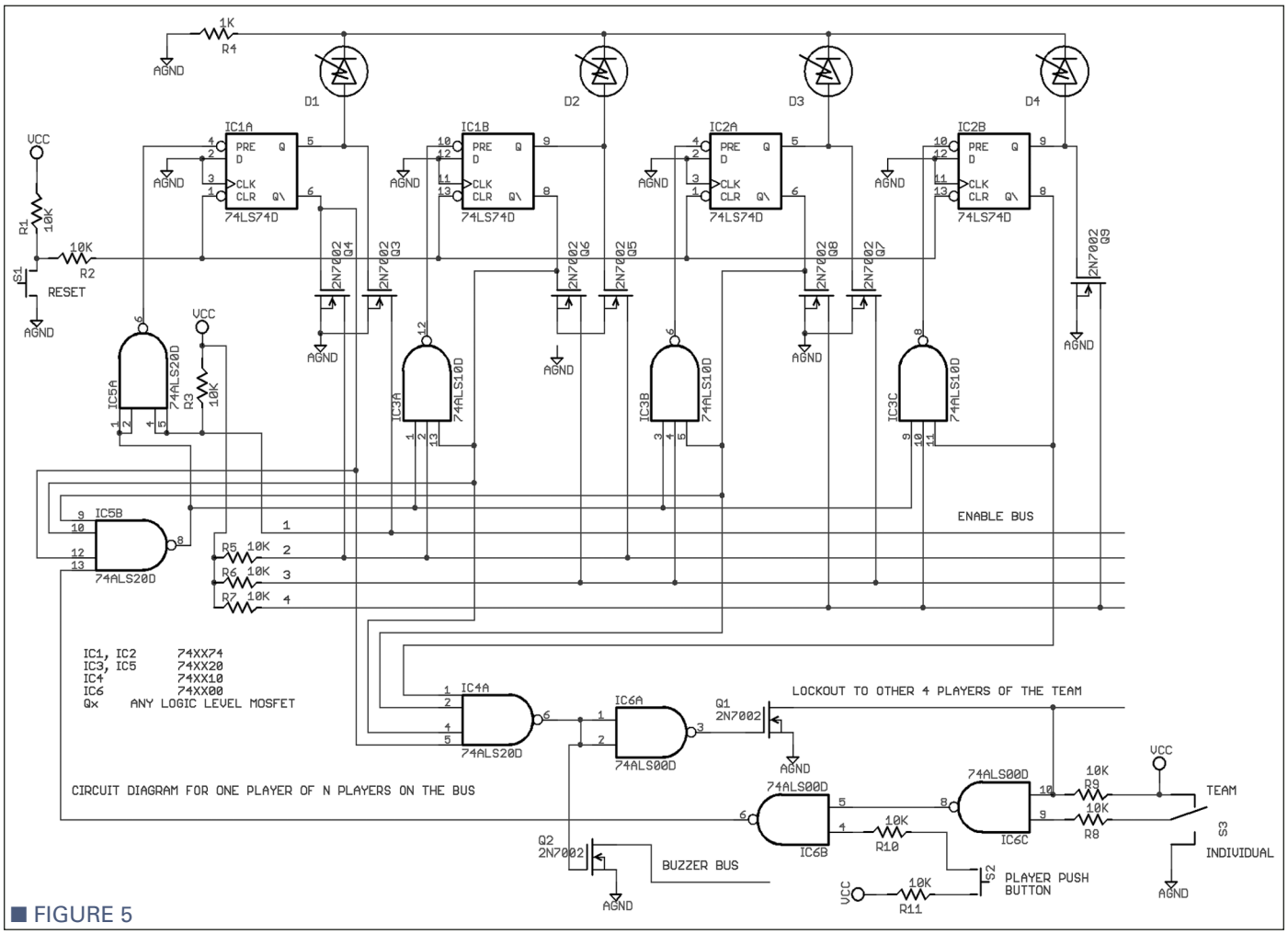
Note that the reset, enable, and buzzer bus goes to all 20 players but the lockout bus goes only to the five players of the team.

CONVERT 33 1/3 TO CD

Q I have a stack of old 33-1/3 RPM records which I would like to transfer to CDs. What hardware and software are needed for this mission?

— Bud Damnjanovic

A You will need a sound card. Look in the back of your computer; if there is a card with three or four 1/8″ phone sockets and symbols for microphone and speaker, you already have it. You probably will need an adapter to plug your record player into the sound card and software. I only did this once; I believe I used Audio Record Wizard V3.97 (ARWizard3), although I also have RealPlayer on my computer. A Google search may turn up other possibilities. **NV**



■ FIGURE 5

NEW PRODUCTS

- HARDWARE
- SOFTWARE
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- TOOLS

NEW ZX MICROCONTROLLER

Elba Corporation announces the first shipments of a new, more powerful multi-tasking microcontroller intended for use by scientists, engineers, experimenters, and hobbyists. The ZX-1281 is a 64-pin TQFP format device targeted to high volume products or resource-intensive applications where additional I/O capabilities are required. All ZX-series microcontrollers are programmed in ZBasic, a subset of Microsoft's Visual Basic (VB6) with microcontroller-specific extensions and other productivity enhancements.

The newest member of the ZX microcontroller family is based on the Atmel ATmega1281 MCU. The primary benefits offered by the new ZX model are increased execution speed, expanded user RAM (7.5K standard, 63K maximum), extended user program space (60K total), additional PWM channels (up to six), and a second hardware serial port. The new ZX-1281 is largely source code compatible with the previously released ZX family members — the ZX-24, ZX-24a, ZX-40, ZX-40a, ZX-44, and ZX-44a.

The single unit pricing of the new ZX-1281 is $49.95. Volume pricing is available. A ZX-1281 Development Board is available to facilitate quick prototyping of a ZX-1281 application. The Development Board, which includes a ZX-1281 device, is priced at $79.95

The ZBasic programming language is a subset of VB6 with extensions suitable for microcontroller programming. The ZBasic compiler can detect common programming defects such as use of a variable before its initialization and other likely errors. The compiler incorporates advanced optimization techniques that help programmers pack more functionality into the available code and data spaces by, for example, eliminating unused or superfluous variables and unreachable code.

Programs for the ZX-1281 may be edited, compiled, and downloaded using a state-of-the-art Integrated Development Environment. The ZBasic IDE provides productivity-enhancing features such as word completion, call tips, auto-indenting, syntax highlight-

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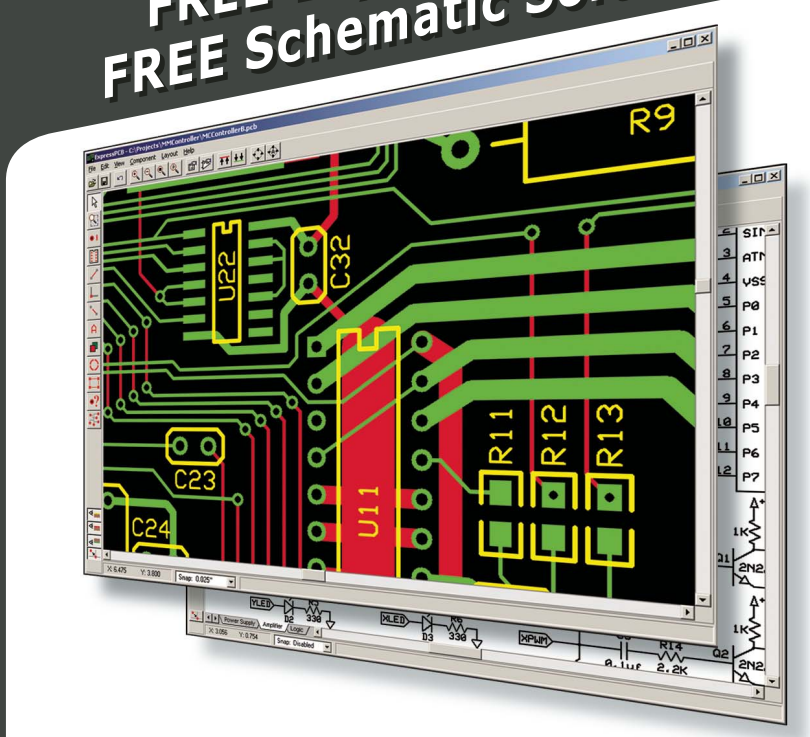

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ing, and undo/redo. The IDE can also be used to perform field updates of the ZX-1281's internal firmware, making it simple to upgrade to new firmware releases as they become available.

For more information, contact:
Elba Corporation
Web: **www.zbasic.net**

NEW PROTOTYPING-FRIENDLY ZX MICROCONTROLLERS

Oak Micros announces two new microcontrollers based on the ZX microcontroller platform. The ZX-128e and ZX-1281e are based on their namesake Atmel AVR ATmega128 and ATmega1281 devices and include a preprogrammed ZBasic Virtual Machine from Elba Corporation. These devices are suitable for the hobbyist and professional alike and provide a powerful, easy to use platform for scientific and industrial control applications.

The new ZX-128e/ZX1281e are similar to the successful Oak Micros ZX-24e/ZX-24ae devices and have a prototyping and breadboard friendly 40-pin dual in-line format that features 32 I/O pins, true voltage level RS-232 transceiver, slide switch to choose between RS-232 and logic voltage levels for serial channel one, LED monitoring on two I/O pins, and a five volt regulator and power monitor LED.

By utilizing the base features of the AVR microcontrollers, these new devices offer a second hardware serial port and four additional PWM channels. Up to 60K bytes of ZBasic program code can be stored in the AVR Flash memory, which as a side benefit provides read protection of user programs and is 20% faster than the previous devices that used 32K bytes of EEPROM. A RAM daughter card allows user programs to address over 63K of RAM for program variables, task stacks, and heap storage. This is an increase from the previous 3.5K bytes that was available for the ZX-24ae device and permits these new devices to be used in RAM intensive applications such as web servers and data collection/management engines. The single unit pricing of the ZX-128e is $69.95 and the ZX-1281e is $79.95. Volume pricing is available.

"These new ZBasic devices together with the ZX-1281 provide a wide range of options and choices for customers" said Donald Kinzer, President of Elba Corporation. "Oak Micros is a strong partner and provides many useful ideas and help to improve and extend the ZBasic platform. A recent ZBasic application note on RS-485 networking, written by Oak Micros, utilizes the powerful multi-tasking capabilities of the ZBasic platform to support master-slave data transfers up to 460,800 baud."

The ZX-128e and ZX-1281e are also programmed using the ZBasic programming language.

For more information, contact:
Oak Micros
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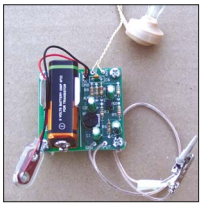

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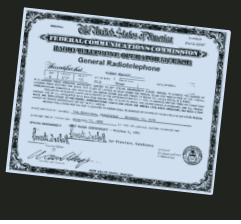

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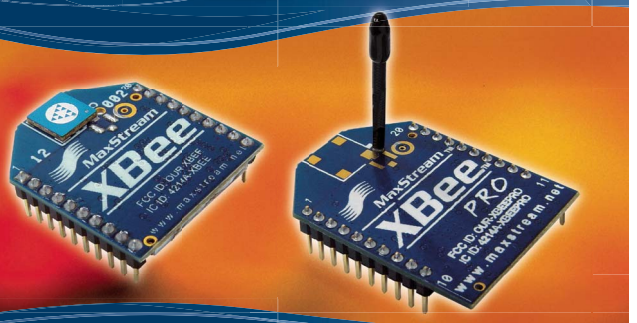

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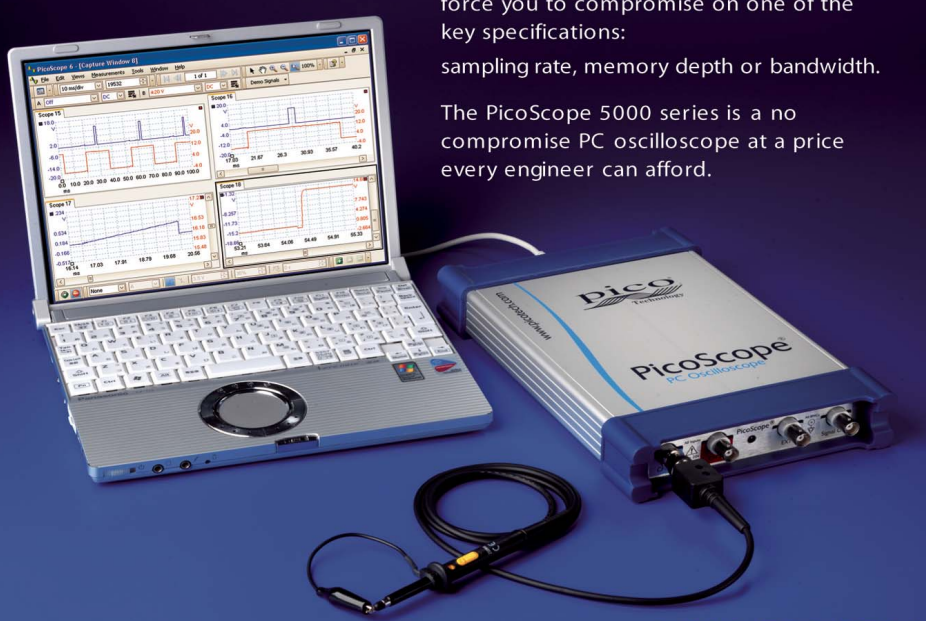

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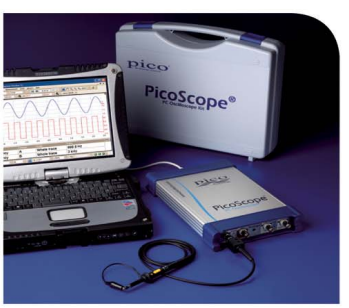

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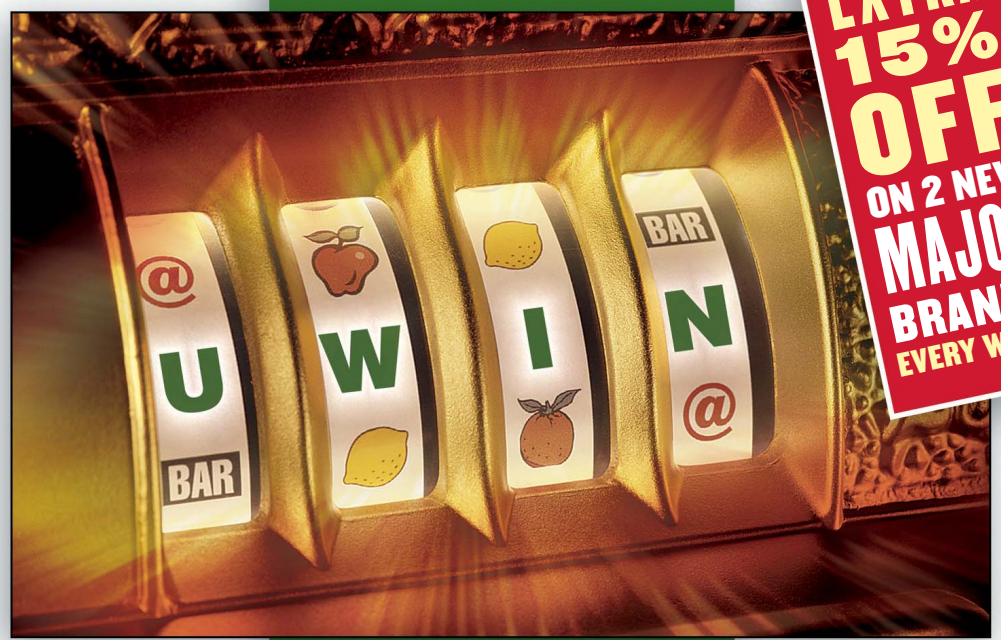

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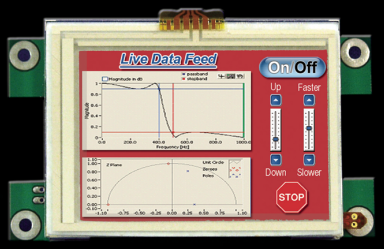

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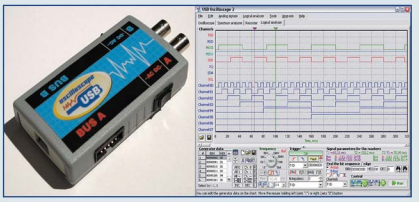

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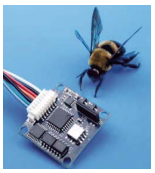

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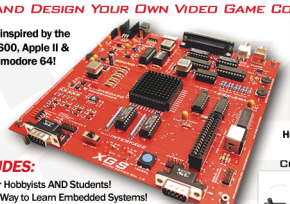

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READER FEEDBACK

Continued from Page 6

a sheet metal break. I did this with two pieces of wood that have a 45 degree bevel on one edge (this gives relief clearance when completing the last part of the bend). Clamp these at the bend line and clamp in a vise. Two more pieces of wood clamped over the other side of the bend line and Voila! you have a hand break! Now pull or push that extended edge toward you or away from you until you have a 90 degree bend. Check with a square to be sure. As for rectangular holes, scribe your layout lines directly on the panel and then "hog" out the hole with a series of the biggest drill that will fit inside these layout lines (in my case, that was a 1/2" drill bit). Then clamp the panel firmly in a vise (or whatever) and file the rest out to the scribe lines. I am sorry for your trouble, but the article was not meant to be a metal working primer, as this is a whole different feild.Most constructors will look for a good buy on a chassis/case or use whatever they have on hand that's close in size, so I didn't dwell on that aspect of construction too much – just enough to give some insight on what could be done.

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THIS MONTH'S PROJECTS

Build an X10 Doggy Dish 36
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Magic Box — Part 2 46

LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

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Build an X10 Doggy Dish

Last month, I gave you details on how to communicate with various X10 computer interfaces. This month, I had planned on showing you how to use each one of those interfaces with a microcontroller. I want to deviate a bit and actually show you how to build a cool project using the CM17A FireCracker.

Over the last 10 years, I have built many different automatic dog watering dishes. Some worked pretty well and others did not. Inevitably, all dishes eventually failed and one conclusion I came to was that it was not practical to automatically fill the dish; as eventually all the systems failed and I ended up with a mess. What I wanted instead was a system that would let us know when the dish needed to be filled. I came up with the following project requirements:

- No probes are to come in contact with the water.
- No floats or other items are to be placed inside the dish.
- The system must be portable and able to be installed under the dish.

While playing with the FireCracker and the microcontroller interface, the idea for this project came to me. The FireCracker (CM17A) is small and gets its power from the control leads. The interface is simple and requires no external components. All that was left was to come up with a way to detect the amount of water in the dish.

The easiest way would have been to sink a couple of leads into the water, but this is not safe for the animals no matter how low the current and voltage is. Floats are a pain and tend to get in the way. In the past, I had used a special platform that measured the weight of the dish. While this system worked well, it was not portable and the mechanics were prone to failure.

I tried using sonar and IR sensors to detect the depth, but they were a failure, as well. Then I remembered an experiment I performed about a year ago using an I/O interrupt (IRQ) as a counter. I set up a DiosPro microcontroller with one of its leads as an IRQ counter and created a routine that would increment a variable each time the IRQ fired. During one of my experiments, I found that if I toggled one of the other ports while I was touching the IRQ port, it would detect the toggled port. My body was acting as a giant antenna for the very sensitive IRQ port and just about any electrical activity would cause the IRQ to fire.

To expand on the experiment, I held the IRQ port low with a 100K resistor. This would reduce the sensitivity, but when I touched the IRQ port, nothing happened. If I touched both the IRQ port and the toggling port, the IRQ would fire with each toggle. I then connected large metal plates to both the IRQ port and the toggle port. I placed them very close without touching and the toggle port would cause the IRQ port to count. This is exactly what I was looking for so I placed the plates against a plastic jug and when filled with water, the IRQ port would pick up the toggle port level changes.

It's the results of this experiment that I am basing this project.

Building Sensor Pads

It's time to create a couple of sensor pads that you can use for your own experiments and eventually use on your own doggy dish project. You will need some foil tape — the kind that you can purchase from the heating and air-conditioning section of your home center. One side is conductive and the other has a very strong adhesive. Take an 8″ piece of foil tape and split it down the middle as shown in Figure 1.

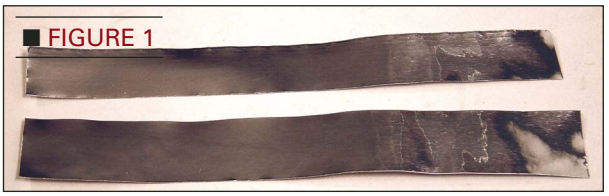
Next, take a 12″ piece of solid hookup wire and strip about 4″ from the end. Lay the wire on one of the tape strips foil side up as shown in Figure 2. Take the other tape strip and remove the adhesive backing and place it over the wire and original strip as shown in Figure 3. Use your thumb to smooth out the bubbles and to make sure the wire is firmly sandwiched between the two strips. You now have a sensor pad. You will need two of these sensor pads. For now, attach the two sensor pads to a jar similar to the one shown in Figure 4. Use cellophane tape so they can be removed later.

Controller Board Construction

Before we can proceed with the first test, we need to build the controller board that will take readings and send out our X10 control codes. We will use a DiosPro 28-pin chip, a Dios Carrier1 board, and a FireCracker X17A. I will provide a complete list of materials at the end of this article along with sources for the various components.

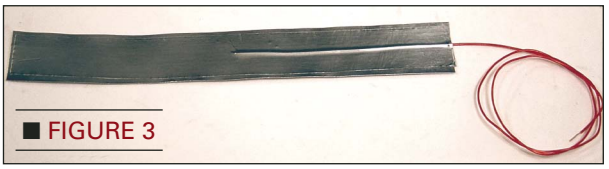
• ***STEP 1 — Build the Dios Carrier Board.*** Use the instructions that come with the Dios Carrier 1 board to assemble it. Don't assemble the two 12-pin headers. When complete, it should look like Figure 5. Install one-pin headers into ports 7 and 13. Install a two-pin header into the two pads marked – and + near the upper right hand of the board shown in Figure 6. Install a five-pin female header into the pads marked –, +, Rx, Tx, and Atn in the lower left hand corner of the board. This header will be used to insert an EZRS232 for programming the DiosPro. Install a 100K resistor between I/O port 7 and Vss as shown in Figure 7.

■ FIGURE 1



■ FIGURE 2

■ FIGURE 3



• ***STEP 2 — Attach the DB-9 Connector.*** Break off a two-pin header from one of the headers that came with the Dios Carrier 1 and solder it to the pins 4 and 5 as shown in Figure 8A. Then break off a single pin and solder it to pin 7 as shown in Figure 8B.

Attach the DB-9 connector to the Dios Carrier 1 as shown in Figure 9. The header pins 4 and 5 are soldered on the top of the board to I/O ports 2 and 3. The header pin 7 is soldered on the bottom of the board to I/O port 0. This connector will eventually connect to the FireCracker.

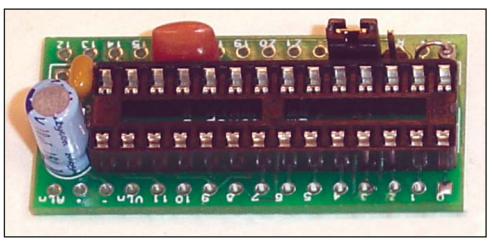
• ***STEP 3 — Final Prep.*** Move the red wire on the battery connecter so that it is located next to the back wire as shown in Figure 10. To do this, you need to pry up the small tab covering the pin. Keeping the orientation of the receptacle the same, push it into the slot next to the black wire. It should snap into place.

Snap off a single one-pin section from the 36-pin female header and solder the end of the wire connected to the sensor pad to this female header. For more strength, slip a piece of 1/8″ heat shrink over the pin and shrink as shown in Figure 11.

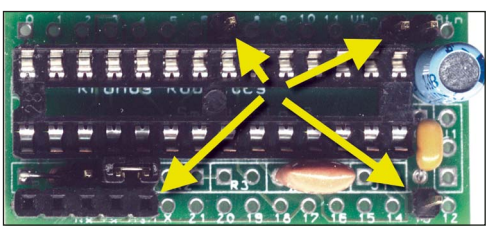
• ***STEP 4 — Sensor Pad Test.*** If you have not done so, you need to assemble and test the EZRS232 board

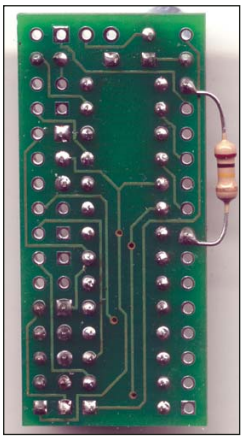
■ FIGURE 4

■ FIGURE 5

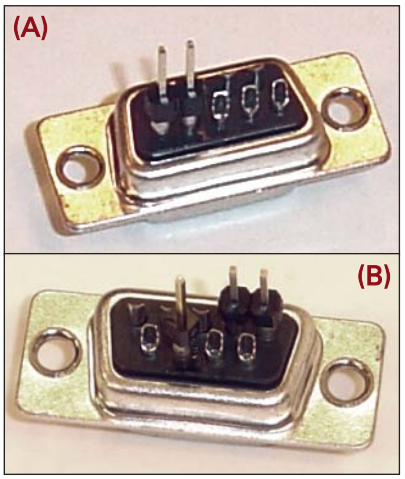


■ FIGURE 6





■ FIGURE 7



■ FIGURE 8

according to the accompanying instructions, then download and install the free Dios compiler.

Insert the Dios Pro chip into the carrier, then plug the EZRS232 driver into the five-pin female connector on the carrier and connect the battery connector as shown in Figure 12. Make sure the orientation of the black and red wires is correct. If they are not, you will damage the DiosPro chip.

Connect the carrier to your PC by using a nine-pin serial cable. All new DiosPro chips contain a small test program that will display a test message on the debug terminal.

Now connect each of the sensor pad female headers to the single pin male headers on I/O ports 7 and 13 that we installed earlier. Schematic 1 shows the complete hookup for this experiment.

Program the code from Listing 1 into the DiosPro. For the Dios Carrier 1, you will need to use an EZRS232 driver. The DiosWorkboards have the RS-232 driver built in so experimentation is much easier.

Once you run the program, it should start reporting 0 in the debug window. Start to fill the jar or container and as the water reaches the top, the sensor pad reading should change to 50.

The program is simple enough. The startirqasm is a simple assembly routine that fires each time there is a change from low to high on port 7. The routine increments the global variable dishvarb. The DishTest routine is called each time you want to test the water level. What it does is toggle port 13 100 times. This is 50 low to high transitions and 50 high to low transitions. Upon entry to the routine, I set the global variable dishvarb to 0 so we get a fresh count with each call.

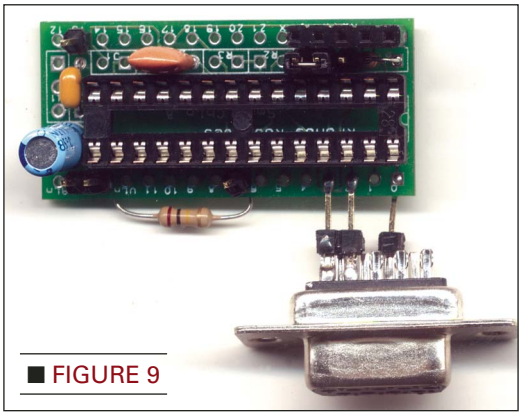
Play with the location of the sensor pads, as well as the 100K resistor. I have found that you may also place the two sensors across from each other on the container.

• ***STEP 5 — Doggy Dish Assembly.*** Dish selection is important. You need to select a dish that has some sort of chamber on the under side. This chamber will be used to house the DiosPro, FireCracker, and battery pack. The bowl shown in Figure 13 is very common, available at most pet and department stores and is available in many sizes and colors. You may also make your own bowl by attaching two bowls as shown in Figure 14. The best way to attach the two is with some industrial double stick foam tape or hot glue or both.

Remove the sensor pads from the jar and, using cellophane tape, attach the two pads near the bottom of the doggy dish bowl across from each

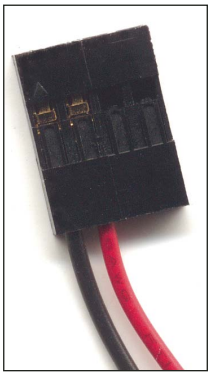
LISTING 1

```
DiosPro
'-------------------------------------------------------
'DDishP1 Simple Water Level Test Program
'-------------------------------------------------------
func main()

  dim irqcount as integer

  'Start INT0 IRQ
  irqglobalstart 'enable global IRQ's
  irqINT0start 'enable INT0 IRQ

loop:
   irqcount=DishTest(13)
   print irqcount
   pause 100
   goto loop

endfunc


'-------------------------------------------------------
'Sensor Test Program
'Will Return 50 if IRQ catches all
' port toggles
'-------------------------------------------------------
func DishTest(tport as integer)
  global dishvarb as integer
  dim x as integer
  output tport
  dishvarb = 0
  for x = 1 to 100
    toggle tport
  next
  exit dishvarb
endfunc


'-------------------------------------------------------
'IRQ handler for INT0 irq
'-------------------------------------------------------
startirqasm INT0
  movlb  .2  ;Need this to access global variables
  infsnz G_dishvarbl,f
  incf   G_dishvarbh,f
endirqasm
'-------------------------------------------------------
```

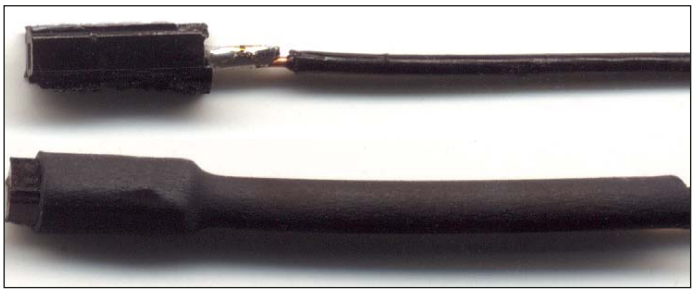


■ FIGURE 9

■ FIGURE 10

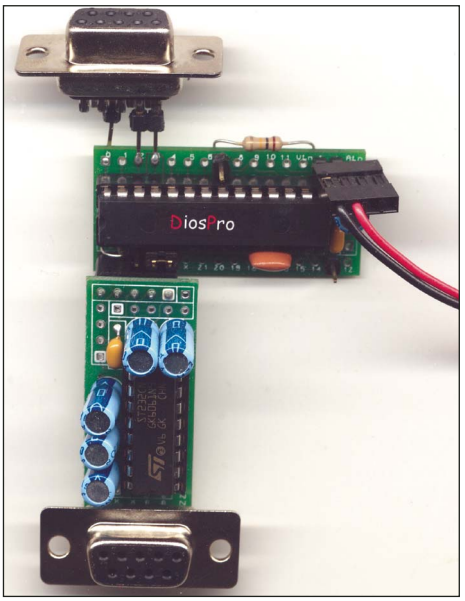


■ FIGURE 11



■ FIGURE 14

■ FIGURE 13



■ FIGURE 12

other as shown in Figure 15.

Set the bowl right side up and connect the sensor pads to the DiosPro and power it up by plugging in the battery connector. Slowly fill the dish with water until the readout starts to display 50. Using a small cup, remove small amounts of water until the display reads 0 once again; this is the point that the dish will alert you when it needs more water.

If you aren't happy with the level, reposition the sensor pads until you are.

• ***STEP 6 — Test the FireCracker Interface.*** Connect the FireCracker to the DB9 connector that you attached to the Carrier 1 board back in Step 2, as shown in Figure 16. Load up the program DDishP2.txt (available from the *Nuts & Volts* website at **www.nutsvolts.com**) and program it into the DiosPro using the EZRS232.

The program is set to turn device K3 on and off, depending on the water level. You can change this by modifying the constants used in the call to the SendX17Adata routines. Connect the sensor pads if they are not already connected and add water to the bowl. The K3 device should turn off as long as the water level is okay. It will turn on when the water level drops below your sensors. The program tests the dish every 10 seconds which seems like a good rate.

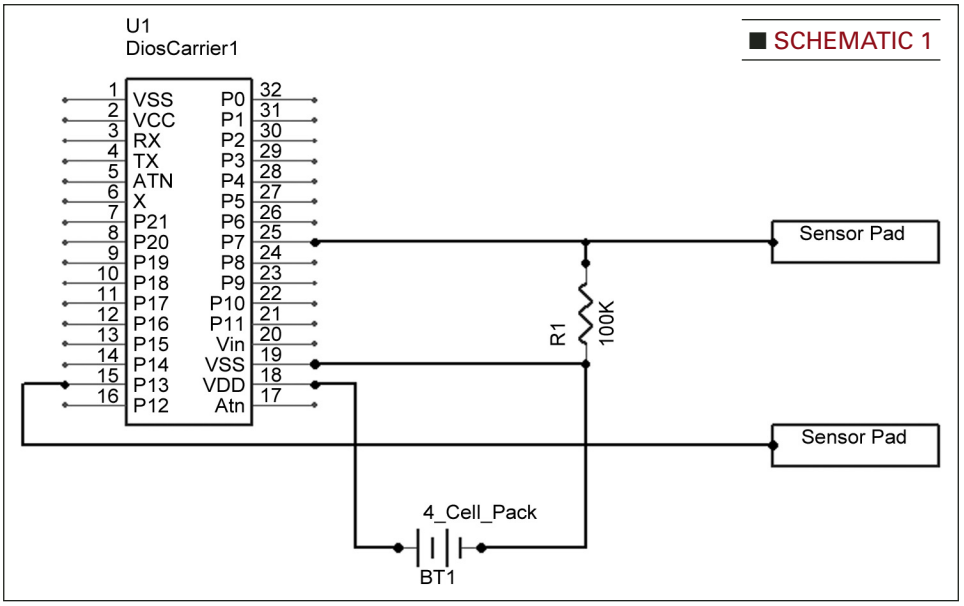
• ***STEP 7 — Final Assembly.*** By this point, we have tested the control system, the sensors, and the water levels and are happy with their operation. It's much harder to program the DiosPro once it has been installed under the bowl.

Dry fit the controller and battery holder first by holding them in place. Make sure you can reach the board with the sensor pad wires as shown in Figure 17. Don't install the batteries and controller too close to any of the sensor pads or they may interfere with the readings. Position the Carrier 1 board so that you can still install the EZRS232 when needed.

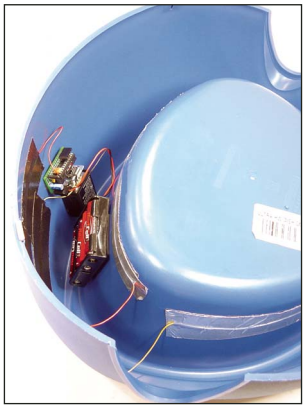
Once you are happy with the location of the controller, place some double stick foam tape on the FireCracker and stick it in place. You will also want to attach some foam tape to the

■ FIGURE 15

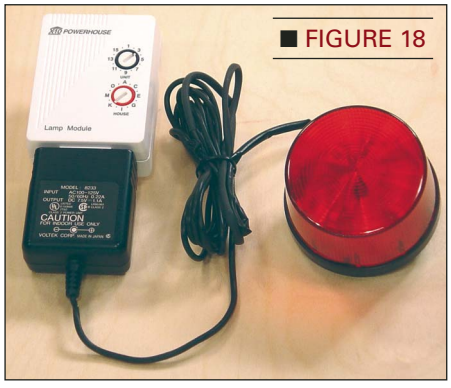
■ SCHEMATIC 1



■ FIGURE 16



■ FIGURE 17



■ FIGURE 18

Carrier 1 board, as well. The board sits higher than the FireCracker so you will need two to three layers of the foam tape for the added height. Attach the four-cell battery holder next. You may also want to use some tape to hold the sensor pad wires in place. Make sure you don't use metal tape for this.

Load up program DDishP3.txt and program it into the DiosPro. This program takes advantage of a few of the hardware features built into the DiosPro. The DiosPro has the ability to be put to sleep and will draw only about 40 µS of power from the battery in this mode. To wake up the DiosPro, we use another feature called the watchdog timer. When turned on, it will wake up the DiosPro after it has been asleep for two seconds. If you look at the code, you will see that I make 130 calls to the sleep command. This causes the DiosPro to stay on a low power mode for five minutes. Once it wakes up, it does a dish test then turns the X10 device on or off depending on the reading. We are providing the power to the FireCracker, so just before we put the chip to sleep the power is removed so that the FireCracker itself does not drain the battery.

Another hardware feature of the DiosPro is the ability to self-monitor the supply battery. We make a call to this routine once each cycle and if the battery voltage drops below 4.24 volts, it will toggle the device five times to warn us.

Final Thoughts

I have been using the dish now for a couple of months and it has worked without a failure. The alkaline batteries I have been using also show no signs of significant drain.

The complete schematic for the final assembly is shown in Schematic 2. Feel free to make modifications. There are several ports available for connecting things like LEDs, beepers, or other devices. You could also run a couple of additional sensor pads to test different water levels. For instance, use port 14 to run a second toggle pad. Just make an additional call to the DishTest routine passing I/O port 14.

As for the water level warning indicator, just about any lamp will work. I use something a little different. I use one of those strobe flashers connected to an AC adapter as shown in Figure 18. I'm using the standard lamp module that came with the CM18 FireCracker kit. The strobe will flash whenever the dish needs more water.

The FireCracker — also known as the CM17A — is not an X10 device, nor does it communicate with the X10 protocol. It is a wireless transmitter that is designed to work with the TM751 transceiver module. While you can purchase the CM17A by itself, it won't do you any good unless you already have a TM751. This is why they created the CM18 FireCracker Kit. This kit contains the following modules:

- FireCracker Module (CM17A)

Links to Parts

AVAILABLE FROM KRONOS ROBOTICS AT **www.kronosrobotics.com**:

■ DiosPro28 — **www.kronosrobotics.com/xcart/customer/product.php?productid=16169**

■ Dios Carrier 1 — **www.kronosrobotics.com/xcart/customer/product.php?productid=16170**

■ EZRS232 Driver — **www.kronosrobotics.com/xcart/customer/product.php?productid=16167**

■ Four-cell Battery Holder — **www.kronosrobotics.com/xcart/customer/product.php?productid=16323**

■ 36-pin Female Header — **www.kronosrobotics.com/xcart/customer/product.php?productid=16291**

■ Nine-pin DSub Plug — **www.kronosrobotics.com/xcart/customer/product.php?productid=16254**

■ 100K Resistors — **www.kronosrobotics.com/xcart/customer/product.php?productid=16195**

■ Heat Shrink — **www.kronosrobotics.com/xcart/customer/product.php?productid=16288**

AVAILABLE FROM **www.X10.Com**:

■ FireCracker — (Note the FireCracker can be purchased cheaper from an eBay eStore.)

AVAILABLE FROM ALL ELECTRONICS AT **www.allelectronics.com**:

■ Strobe Light — **www.allelectronics.com/cgi-bin/category/605/Strobes.html**

AVAILABLE FROM HOME CENTER:

■ Foil Tape — Standard HVAC metal tape.

■ Double Stick Foam Tape — Used to secure the Dios Carrier 1 and FireCracker to the inside of the bowl.

■ Hookup Wire — I used wire removed from standard telephone cable (Cat 3).

AVAILABLE FROM PET STORE:

■ Water Dish — I purchased the bowl I used from PetSmart. I have seen them at various department stores, as well.

Web Links

■ Kronos Robotics
www.kronosrobotics.com/xcart/customer/home.php

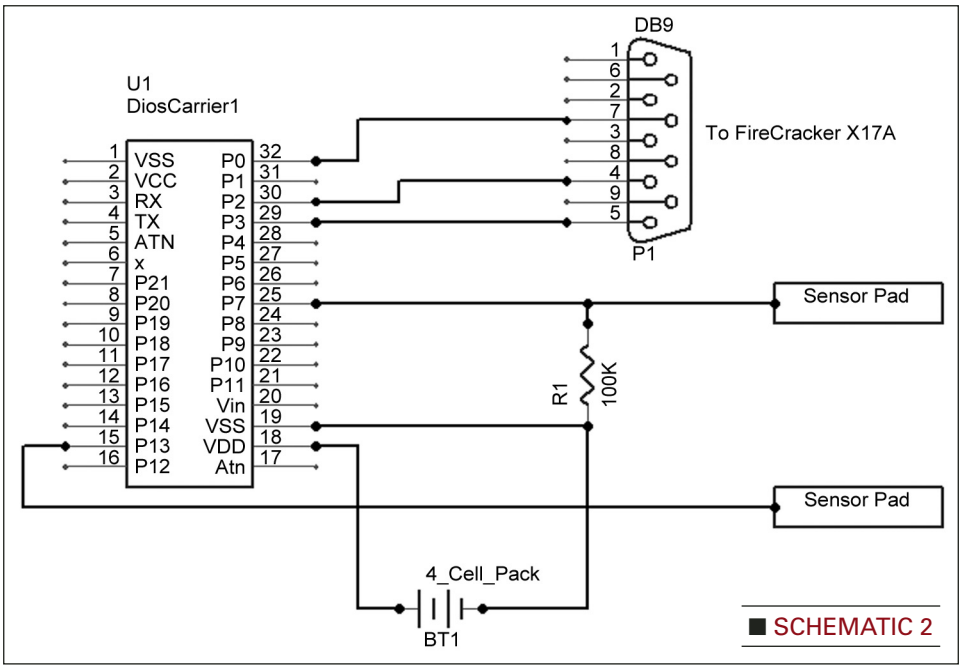
■ KRMicros
www.krmicros.com/Development/ZeusPro/ZeusPro.htm

www.krmicros.com/Development/ZeusLite/ZeusLite.htm

■ SmartHome
www.smarthome.com/1132b.html

■ X10
www.x10.com

- Transceiver Module (TM751)
- Lamp Module (LM465)
- PalmPad Remote Control (HR12A)

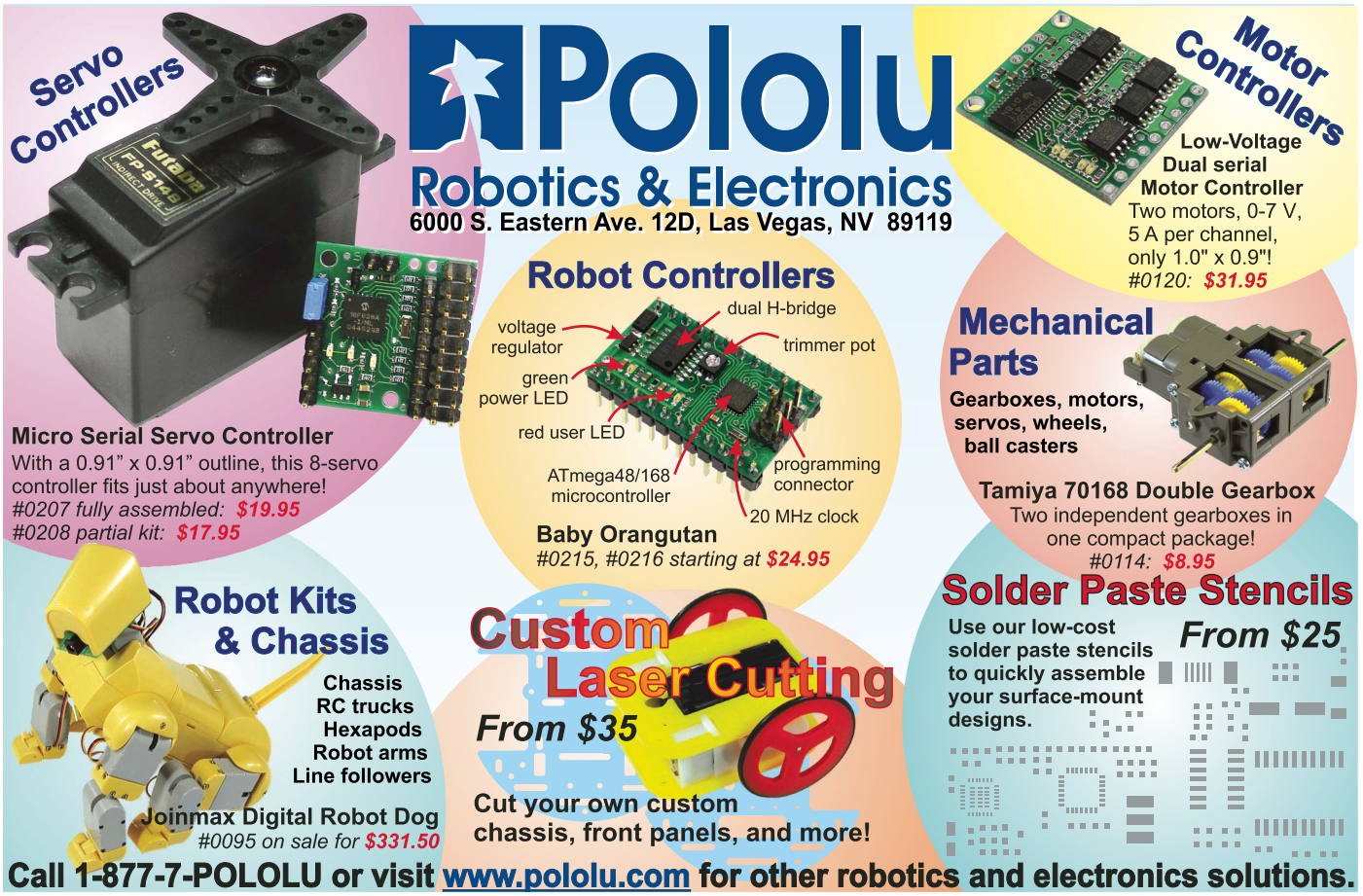


■ SCHEMATIC 2

Since the FireCracker is so easy to use with both a PC and microcontroller. I recommend at least one CM18 Kit. After that, you may purchase additional CM17A units for as little as $12.

As for projects using a CM17A and microcontroller, they are endless. I have already started on a sonar car parking aid for the garage.

All the example programs, as well as the source are available for download at **www.kronosrobotics.com/Projects/x10b.shtml**. **NV**



BUILD A FLOOD DETECTION ALARM

Wouldn't it be great to detect a flooding issue before it's too late?

Well, this device can detect when rising water occurs. The circuit shown in Figure 1 is a schematic for a flood detection alarm.

This project consists of a box containing circuitry and the water probe assembly. When water touches the probe assembly, an alarm will sound. A relay is provided to switch on a water pump. As long as the probe assembly is in contact with the water, the pump switch will remain on. The alarm can be shut off with a switch once the flooding has been detected. Optionally, a 12V lantern battery can be used as a back-up power source if the power from the wall transformer is interrupted.

Circuit Description

The circuit in Figure 1 consists of a 700 Hz oscillator, rectifier, threshold detector transistors, and drive transistors. U1, R1, R2, and C1 form the 700 Hz oscillator. This drives probe P1 on TB1. When water touches probe P1 and P2, P2 picks up the square wave. The signal at P2 is rectified by D1 and charges C4. Q1 is used as a threshold detector. If the charge on C4 reaches a threshold of approximately 600 mV, Q1 turns on. When Q1 is on, driver transistors Q2 and Q3 are also on.

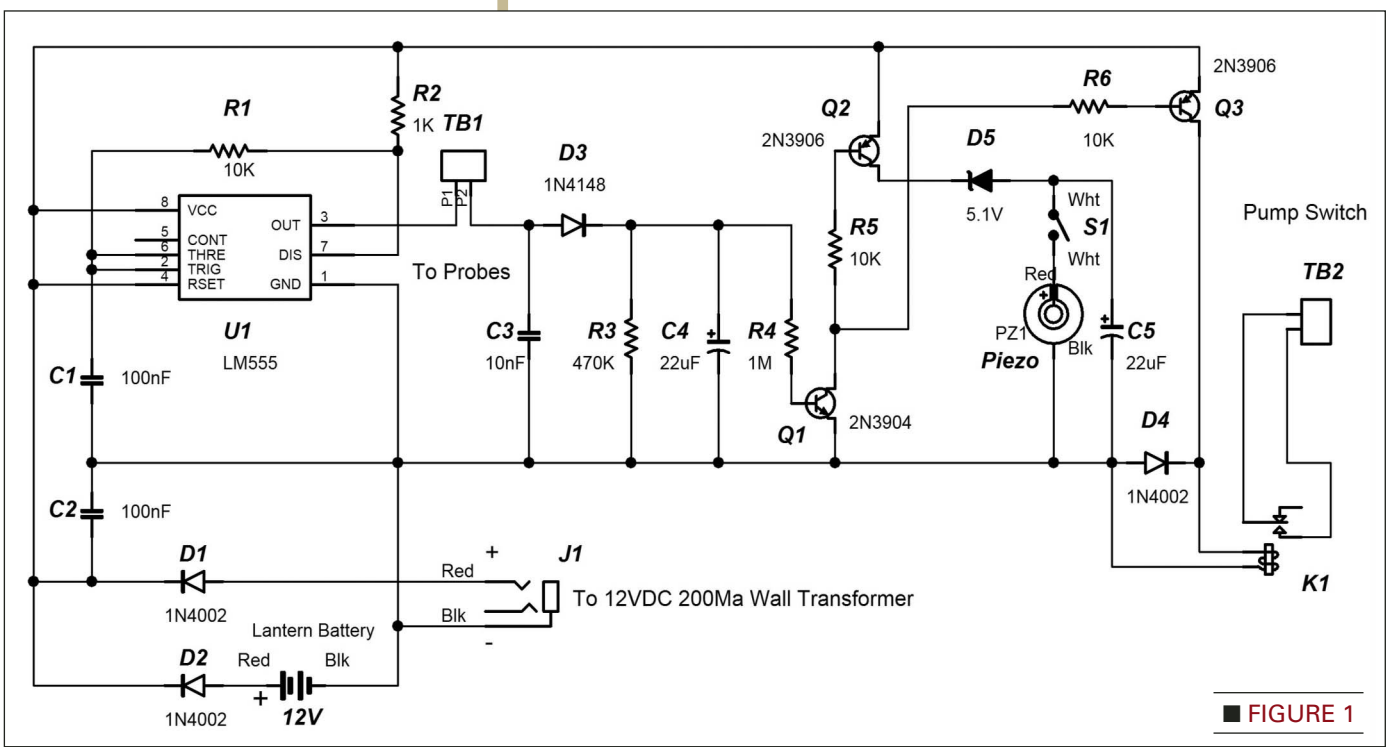
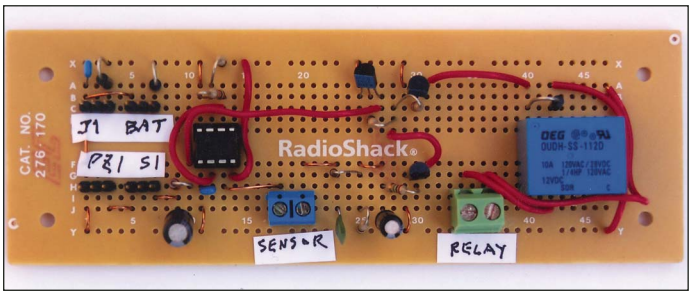
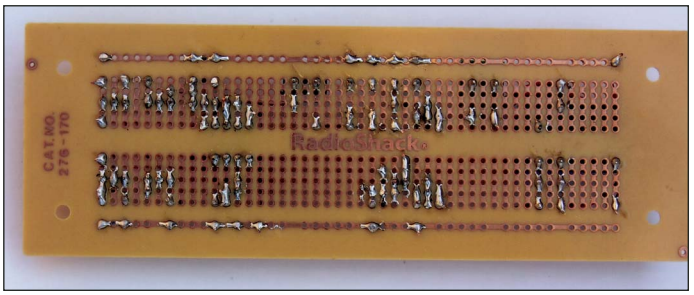


FIGURE 1



■ PHOTO 1



■ PHOTO 2

Q2 drives the piezo alarm and Q3 energizes the pump switch relay coil. D4 is used to eliminate the back-EMF when the relay coil voltage is turned off. C4 remains charged when the probes detect water. If the water level falls below the probe tips, C3 discharges through R3, providing a time delay in turning off Q1. This means that the relay will not chatter when the probes are just barely in contact with water.

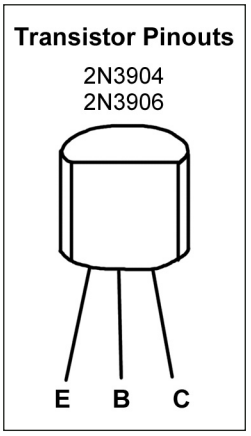
The unit is powered by a 12 VDC 200 mA wall transformer. However, the device can operate from a lantern battery as a backup power source (optional). The Water Detection Alarm (WDA) will draw power from the greater of the voltages at the anodes of D1 and D2. When power is applied from J1, the voltage at the anode of D1 will generally be greater than the 12V battery. If the voltage from the wall transformer fails, a lantern battery can power the circuit through D2.

Construction

Photo 1 shows the top side of the PCB (printed circuit board) and Photo 2 shows the reverse side of the PCB. The Parts List shows the component references. Be sure to use an eight-pin socket for U1. Install the parts on the perfboard. Transistor pinouts are shown in Figure 2. Attach 8″ of red wire to the TIP terminal of J1, and 8″ of black wire to the RING terminal of J1. Then connect two 8″ white wires to switch S1. Also connect a 12″ red wire to the + terminal of the 12V battery and another 12″ black wire to the – terminal of the battery. These wire colors are shown on the schematic in Figure 1.

The connections can be made by soldering the wires directly to the PCB, or they can be made using a female crimp housing connector mated to a .100″ male header soldered to the PCB. Next, construct the probe assembly. Start with a 1.5″ by 2″ piece of single sided, copper clad PCB. Put 3/4″ pieces of tape on both sides and then etch. After etching, there should be copper foil as shown in Photo 3. (the probe assembly). Drill the three holes as indicated in the photo. Take two 4″ lengths of 12 Ga wire and solder to the PCB. It may be necessary to use a 100 watt soldering iron to do this. Bend the wire at an angle such

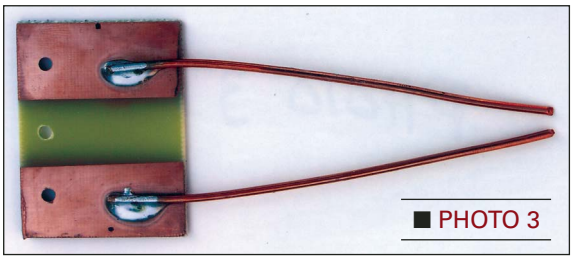
■ FIGURE 2



PARTS LIST

PART	DESCRIPTION	PART NO.	SUPPLIER	COST
❑ U1	LM555CN	LM555CNNS-ND		$1.04
❑ R1, R5, R6	10K 5% 1/4W	10KQBK-ND		5 for $0.27
❑ R2	1K 5% 1/4W	1KQBK-ND		5 for $0.27
❑ R3	470K 5% 1/4W	470KQBK-ND		5 for $0.27
❑ R4	1M 5% 1/4W	1MQBK-ND		5 for $0.27
❑ C1, C2	100 nF	478-3187-ND		$0.24
❑ C3	10 nF	478-2462-ND		$0.24
❑ C4, C5	22 µF 35V radial electrolytic	P1188-ND		$0.31
❑ Q1	2N3904	2N3904FS-ND		$0.16
❑ Q2, Q3	2N3906	2N3906FS-ND		$0.18
❑ D1, D2, D4	1N4002	578-1360-1-ND		$0.04
❑ K1	10A SPST relay	275-248A	RS	$4.49
❑ J1	1/8″ phone jack	274-249	RS	$2.99
❑ PZ1	Piezo buzzer	273-057	RS	$10.49
❑ TB1, TB2	PCB terminals	276-1388	RS	$2.29
❑ S1	SPST toggle switch	275-624	RS	$2.99
❑ Case		270-1805	RS	$3.79
❑ Eight Pin Socket		ED3308-ND		$0.42
❑ Terminals	Ring tongue connector	64-3032	RS	$1.99
❑ Four Standoffs	4/40 1/2″ Nylon standoffs	1902CK-ND		10 for $5.17
❑ Ten Screws	4/40 1/4″ screws	Varies	HWS	
❑ Two Screws	4/40 3/8″ screws	Varies	HWS	
❑ Four 4/40 nuts		Varies	HWS	
❑ Hookup Wire		Varies	HWS	
❑ Wall Xfmr	12 VDC 200 mA transformer	Varies		

All part numbers are DigiKey except for RS part numbers (RadioShack) and HWS (your local hardware store).



■ PHOTO 3

that they are separated by 1/8″ at the tips. Next, make the cable that goes from TB1 to the probe assembly as follows. Cut two lengths of wire long enough to reach the case containing the circuit board from the probe assembly. Once these wires are cut, twist them together with a variable speed drill until they have about eight turns per inch. Then, strip about 1/2″ of insulation from the end of each wire and tin.

One end of the twisted pair has ring tongue connectors soldered to them. These connectors are mounted to the probe assembly with two 4-40 1/4″ long screws and two 4-40 nuts. The other end of the twisted pair is connected to terminals P1 and P2 of TB1 on the circuit board.

Testing and Assembly

Connect the unit to the 12V wall transformer. Then check the voltage between U1 pin 8 and U1 pin 1. The meter should read between 12 VDC and 18 VDC. If this reading is zero, check for proper installation of D1 and J1. When the voltage checks out, install U1 in its socket. Verify that the wires from the probe assembly are connected to P1 and P2. Then place the probe tips into water. The piezo alarm should sound. If the piezo is silent, flip the switch S1. If the alarm is still silent, check the installation of Q1, Q2, and Q3.

Once the alarm is working properly, mount the circuit board, J1, S1, and PZ1 in an appropriately sized case. Orient the switch S1 so that the piezo alarm is enabled when S1 is in the 12:00 position. Drill holes in the case to route the wires from TB1, TB2, PZ1, and the lantern battery. Also drill a hole to mount J1.

Use

Verify that the probe wires are connected to TB1. The TB2 terminal block is connected in series with the pump motor and the power source for the pump motor. The relay contact rating is 10A at 120 VAC. Once all of the necessary connections have been made, attach the lid to the case. When mounting the water detection alarm, care must be taken to install the unit, as well as the wall transformer in a place high above the expected flood level. The probe assembly should be placed such that the probe tips are exposed to water when flooding occurs. A 3/16″ mounting hole on the probe assembly makes it easy to install. **NV**

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This unique DIY construction project blends electronics technology with subtle magic and hand craftsmanship.

This concluding part examines the theory of operation, installation and assembly, testing, and verification that the design works properly. It also presents mini-tutorials on Hall-Effect and magnetism. This allows you to more fully understand and appreciate this project.

THE MYSTERIOUS MAGIC BOX Part 2

Carefully follow these instructions to avoid any problems with sensor alignment, soldering bridges, and proper placement of deliberate shorts on the PC board. We'll help you recognize the differences in component selection and placement in the two kit versions which are available for purchase, for your convenience.

Magnetism and the Hall Effect

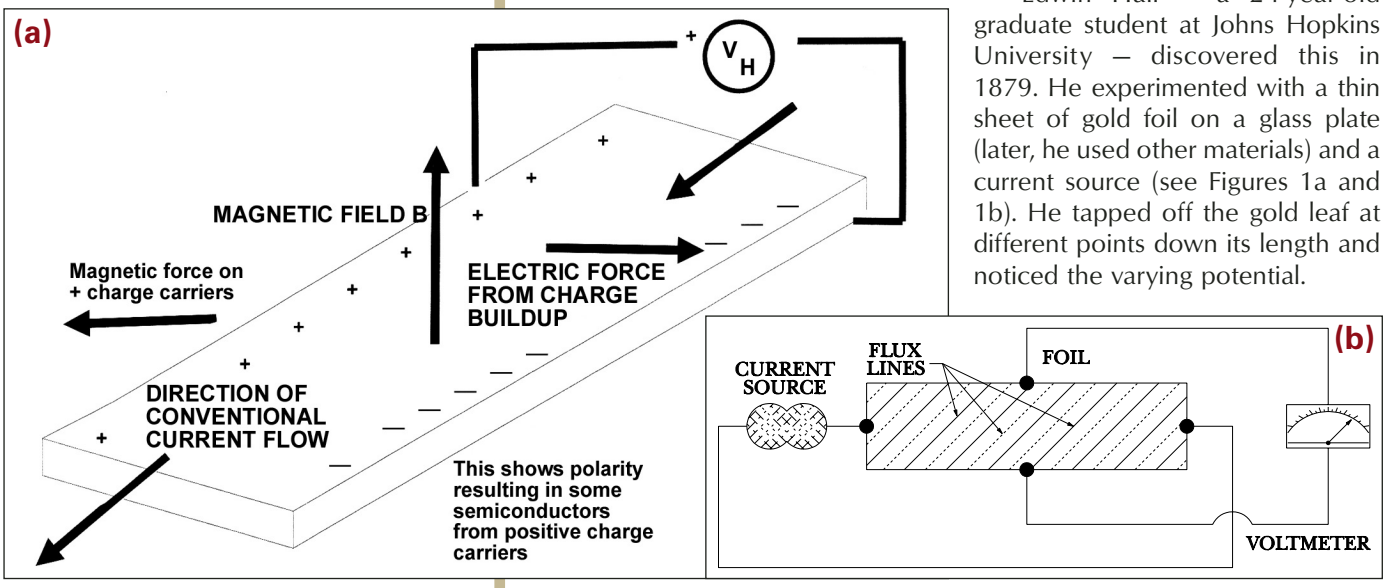
Sometimes we take the simplest things for granted that profoundly influence us. In this project, it is magnetism and the Hall effect that advantageously exploits magnetism.

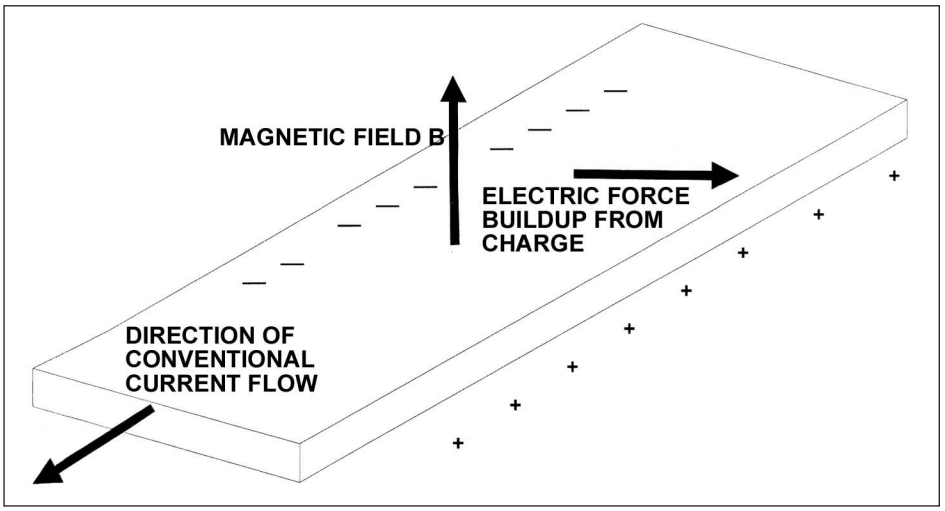
The Hall Effect Phenomenon

When an electric current flows through a conductor in the presence of a magnetic field, the magnetic field exerts a transverse pressure on the moving charge carriers. This, in turn, pushes these carriers to one side of the conductor. This is most conducive and therefore prominently occurs on thin, flat conductors. As the charge accumulates on the sides of the conductor, it balances this magnetic influence. This produces a measurable potential or voltage between these two sides. This phenomenon is known as the Hall effect.

Edwin Hall — a 24-year-old graduate student at Johns Hopkins University — discovered this in 1879. He experimented with a thin sheet of gold foil on a glass plate (later, he used other materials) and a current source (see Figures 1a and 1b). He tapped off the gold leaf at different points down its length and noticed the varying potential.

■ FIGURE 1. The Hall effect phenomenon of charge accumulation on the conductor's edges under the influence of a current source.





■ FIGURE 2. The magnetic field must be perpendicular to the Hall effect's active surface.

Interacting Perpendiculars

In order to create the Hall effect potential, the magnetic field must be perpendicular to the Hall element. The ratio of the voltage created to the product of the amount of current and the magnetic field divided by the element thickness is the Hall coefficient. This characterizes the material comprising the element.

Where Theory Meets Practicality

The Hall effect occurring perpendicular to a magnetic field (see Figure 2) is why you tilt this project's Hall effect sensors upward. These 1/4" diameter magnets in the pawns' base produce lines of flux which are most concentrated directly downward. Magnetic lines of flux do indeed emanate in an almost spherical fashion (see Figure 3). However, as you deviate farther from the center-line, the flux intensity diminishes dramatically. This strategic magnet placement directly exposes the sensors' façades to the strongest magnetic field. This further ensures that your project's missing pawn detection scheme will remain as reliable as our design intended it to be.

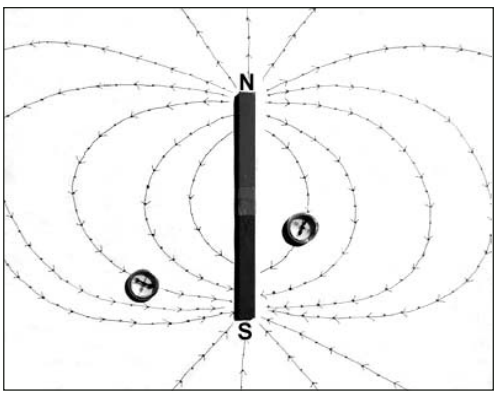
The sensors' façade has writing on it to distinguish it from the non-active side. Notice where it says "branded" (see Figure 4). The A3214A sensor is too small for all of that, so you will just see a 14A nomenclature on it. Use the white Nylon spacers to ensure these sensors assume this upward orientation. They will just slightly bend over the lip of the spacers for proper alignment under their respective magnets (embedded within the pawns).

Nylon Spacers

If you decide to purchase a kit, it will come with two sizes of spacers. They appear identical until you place them side-by-side. One is slightly taller than the other. The taller spacers are for standing off the PCB (printed circuit board) from the acrylic sheet. In the six-pawn version, there will be six shorter spacers to offset the six sensors to a distance that is virtually next to the magnets for reliable activations.

Helping Theory Comply with Practical Constraints

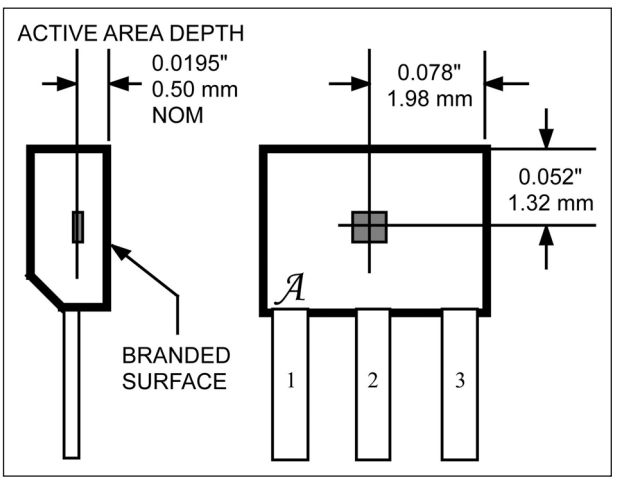
The white Nylon mounting hardware secures and "cradles" the sensors. It does so without use of traditional ferrous metallic hardware. This ensures no magnetic field interaction from metallic hardware that could diminish the effectiveness of the magic trick. (Imagine what would happen if one field coupled from one sensor to an adjacent sensor!)



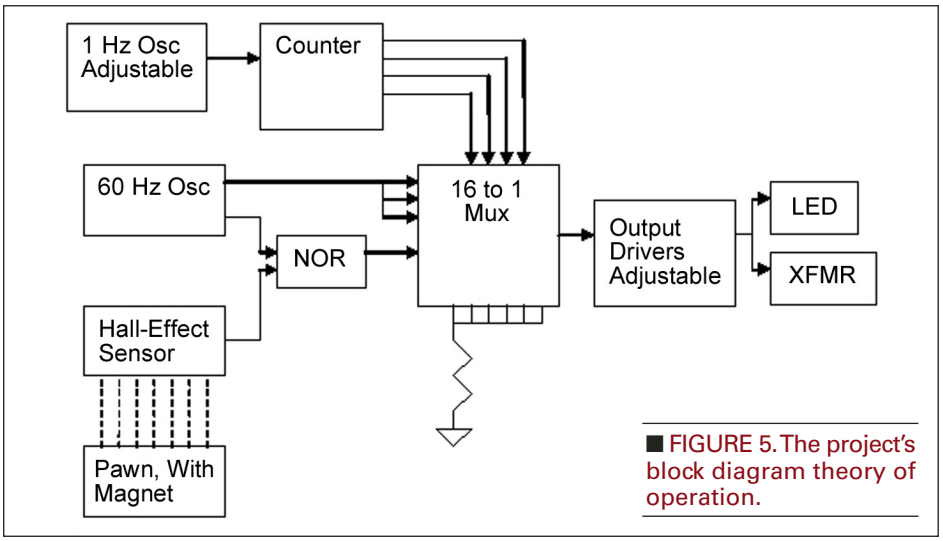
■ FIGURE 3. Magnetic lines of force and their typical convex spherical pattern. Artwork courtesy of the Regents of the University of California.

Magnetism: A Historical Perspective

Magnetism's first observances occurred around 600 BC in the district of Magnesia, Thessaly (one of the 13 peripheral states of Greece). Certain stones in this region either attracted or repelled one another. Touching one of these stones with an iron needle made it orient itself like the stone; thus, the origin



■ FIGURE 4. The Hall effect sensors' "branded" façade where an abbreviated part number would appear. Artwork courtesy of Allegro Microsystems.



■ FIGURE 5. The project's block diagram theory of operation.

of the compass. This acted like a lodestar, or direction finding star referenced to e.g., Polaris. The name comes from lodestone (magnetite, Fe_3O_4) since lode meant "way" in Middle English, and magnet evolved from Magnesia.

In 1269, Frenchmen Peter Peregrinus and Pierre de Maricourt, used a compass and a spherical lodestone to discover invisible lines of force surrounding the sphere at opposite ends. Maricourt called these points the North and South Poles. In 1600, William Gilbert systematically studied terrestrial magnetism and demonstrated that the Earth itself is a large magnet. In 1820, Hans Christian Oersted proved a relationship between magnetism and electricity, and in 1825, William Sturgeon invented the electromagnet. This prompted Michael Faraday's theories on electromagnetic induction and development of the transformer, alternator, and dynamo.

In 1821, Oersted noticed the flow of the electric current in the wire-deflected compass needles. Andre-Marie Ampere pursued this to discover that magnetism was quite different from popular belief. Ampere concluded it was a force between electric currents: two parallel currents in the same direction that attract, and in opposite directions that repel.

The Human Eye as a Light Sensor

Our eyes must function over a wide range of luminance levels (light intensity per given area). During a normal day, our eyes continuously sample information as images projected onto our retinas (the light sensitive nerve tissue in your eye that converts images from your eye's optical system into electrical impulses sent by the optic nerve to your brain). Our brain integrates or averages these objects to make them appear stable or smoothly moving.

The time our brains require to collect and process these images limits our eyes' or visual system's ability to tolerate rapid change. If the rate at which our eyes see intermittent stimuli is slow, our eyes perceive this as acceptable images with only changes in intensity. This is sensation flicker. Flicker ceases above a certain critical rate. This is the critical flicker frequency (CFF).

The Ferry-Porter Law

The Ferry-Porter Law states that CFF is proportional to the logarithm of the luminance of the flickering stimulus (L). Equation 1 states that:

EQUATION 1:

$$CFF = a \log L + b$$

Here, a and b are constants. This relationship is valid over a wide range. The above equation implies that when you plot CFF as a function of log L, the straight line identifies the region where the Ferry-Porter Law is valid. Increasing the intensity of your test stimulus also increases your flicker perception. This is why when your computer monitor flickers, decreasing the intensity eliminates this flicker. In fact, the reason NTSC television signals use a 30 Hz frame rate with two interleaved halves to get a 60 Hz rate is to minimize flicker.

Theory of Operation

The I/O Basics

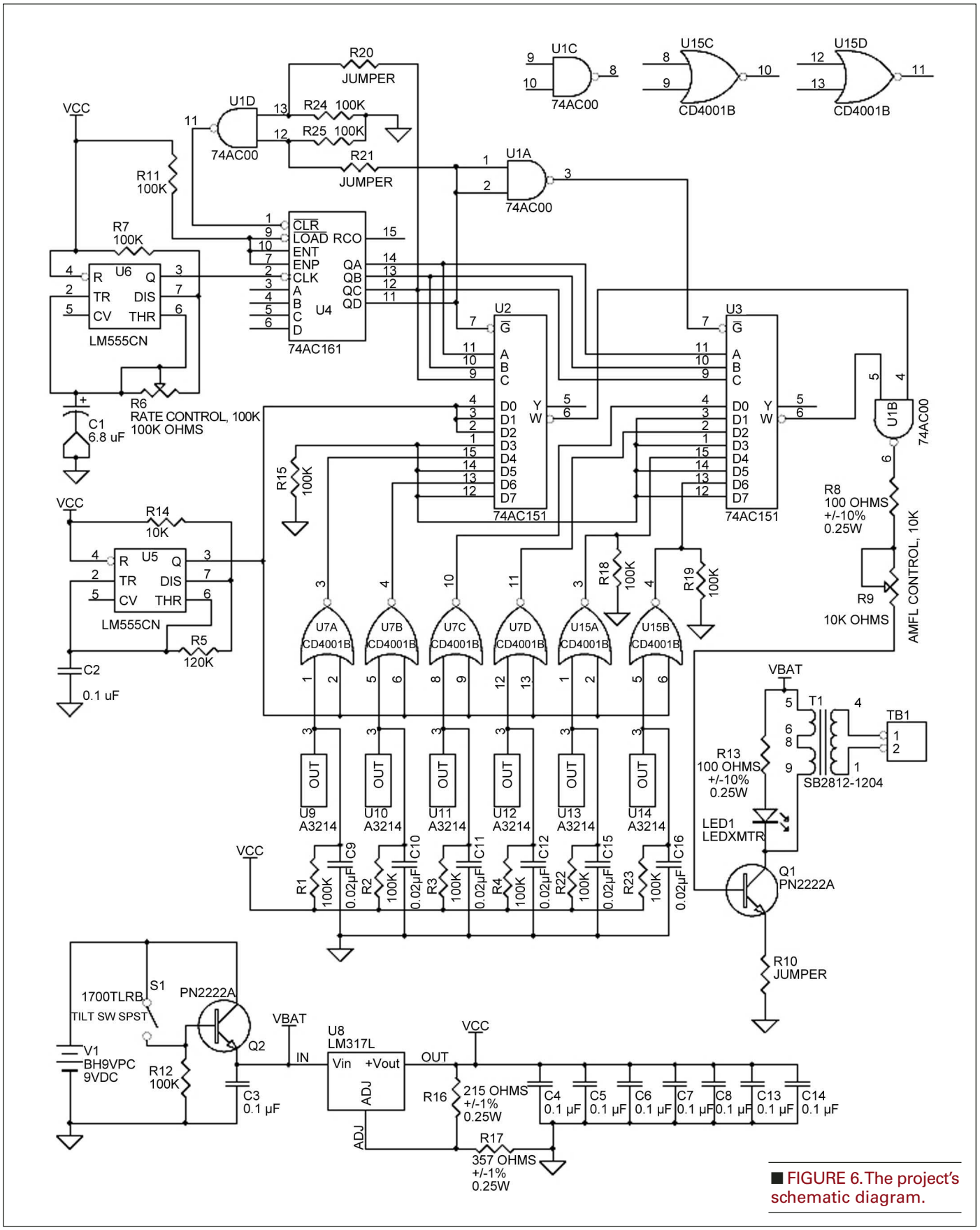
There are two outputs — the visible LED and the transformer — that produce the tingling sensation you feel on the back hinges. We flipped the transformer around and applied the input to its secondary, forming a step-up transformer. Figure 5 is a functional block diagram. Each ouput has one-second pulses of 60 Hz up to seven times (see the sidebar on CFF). When you view the LED, it appears to be on for the entire pulse because the human eye cannot distinguish 60 pulses a second. There are either four or six Hall effect sensor circuits as inputs. (Refer to Figure 6.)

The Selection Process

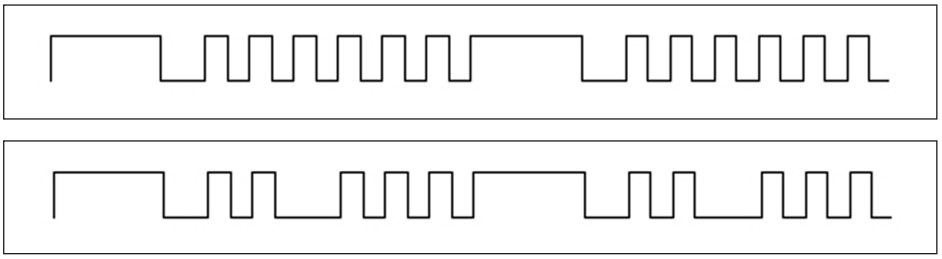
The 16-to-1 multiplexer selects one channel for each state of the four-bit counter. The first three states select the 60 Hz oscillator directly. The fourth, sixth, eighth, 10th, 12th, 14th, and 16th channels are tied to ground

Critical Frequency Flicker (CFF)

CFF is the transition point of an intermittent light source where the flickering light ceases and appears as a continuous light. Marks and Bornstein (1973) found that flicker frequencies ranged from 20 to 35 Hz in normal healthy human eyes. This is where you start to experience a compromised ability to detect flicker and start to incorrectly interpret it as a continuous light source. You experience this here since 60 Hz appears to you as a continuously on light source (LED). Various factors determine humans perception of flicker. These include the intensity and size of the stimulus.



■ FIGURE 6. The project's schematic diagram.



■ FIGURE 8. A timing diagram of all six Hall effect sensors and the starting bit showing a missing pawn in Position #3.

or low. The fifth, seventh, ninth, 11th, 13th, and 15th channels connect to the NOR gate's outputs. The inputs to the NOR gates are the 60 Hz oscillator and one each of the Hall effect sensors. With no magnetic field present, the sensor is inactive and the output is pulled high. The high state blocks the 60 Hz oscillator signal from appearing at the multiplexer input.

When the sensors are in the presence of a sufficiently strong magnetic field, the output switches low. The low state allows the 60 Hz oscillation to pass through to the multiplexer input.

The Electronic Detection Process

The resultant effect is one pulse of 60 Hz (which appears to your eye as a continuous illumination) about three seconds long. (Again, refer to the sidebar on CFF for a more detailed discussion of flicker rates). This marks the start of the sequence. There are six distinct times for pulses of one second duration; one for each of the sensor circuits (see Figure 7).

If one of the pawns is missing (for example, number three), there will be a missing pulse (see Figure 8).

Multiplexing

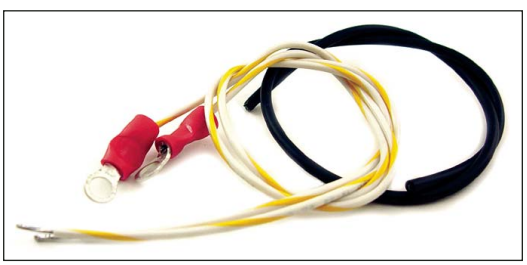
We created the 16-to-1 multiplexer by combining two 8-to-1 multiplexers with two NAND gates. One NAND gate is used to invert the most significant output of the counter to the disable input of the first 8-to-1 multiplexer. Thus, the first 8-to-1 multiplexer is only selected for the first eight counts. The noninverted most significant output is routed to the disable input of the second 8-to-1 multiplexer. The second multiplexer is therefore selected for the remaining ninth through 16th counts. The two multiplexer's inverted outputs are connected to a NAND gate. Inverting the inputs of a NAND is equivalent to an OR gate, so the NAND gate passes the output signal of whichever multiplexer is active.

The Four-Sensor Version

This version is slightly different. The counter is reset after 12 states, so the multiplexer, in effect, becomes a 12-to-1 multiplexer. The circuit remains a 16-to-1 multiplexer, however, four channels are never selected. The counter reset occurs when the two highest significant bits (the "eight" and "four" outputs) go high at the same time. These two outputs are gated through a NAND to create the counter reset signal.

A common PCB can cleverly accommodate both of these two circuit's requirements. The counter reset for the four-sensor system is used when the two most significant outputs are individually jumpered (the jumpers are labeled R20 and R21) to the counter reset NAND circuit. The counter reset NAND circuit is disabled for the six-sensor system by leaving out the jumpers (R20 and R21) for the inputs of the NAND and installing pull-down resistors R24 and R25 instead.

When there are only four sensors, the second package of two-input NOR gates, U15, is not needed, so it is not installed. This leaves two of the multiplexer channels floating, so they are tied low through two additional pull-down resistors, R18 and R19.



■ FIGURE 9. The stripped and pre-tinned wire and optical cable.

■ FIGURE 7. A timing diagram of all six Hall effect sensors and the starting bit.

Quick Summary

To summarize the differences in the two versions: Install resistors R18, R19, R20, and R21 for the four-sensor version, but omit them in the six-sensor version. For the six-sensor version only, you install Hall effect sensors U13 and U14, associated pull-ups, and capacitors (R22, R23, C13, C14, C15, and C16), U15 (the second package of two-input NOR gates), R23, and R24.

The Assembly and Testing Phase

If you have purchased a kit, you begin this phase by removing the parts from the box and taking a cursory and then more detailed parts inventory. Next, you will assemble the wooden cradle, pawns, top panel, acrylic sheet, and install the felt and paper pads. You then assemble the PCB and finish by testing the project.

Ease of Kit Assembly

To facilitate assembly and testing, we pre-cut the optical fiber cable and wires, then pre-stripped and tinned (solder dipped) one end of each of the two wires and attached a #6 lug on the other (see Figure 9). We pre-cut all wooden pieces and pre-drilled the pawns' bases for easier magnet insertion.

There is an LED built in for test purposes on both versions. This test LED does double-duty on the enhanced version. It is an LED with a shroud and optical fiber that also serves as the missing pawn visual detector. The LED on the standard four-pawn version is a stand-alone purplish-blue LED that you observe during the check-out procedure. It is not visible to the outside world as part of visual detection scheme.

Power Conserving CMOS ICs

This project's ICs — including Hall effect sensors — are all CMOS. The two 555 timer ICs can also operate up to 2 MHz. The CMOS high input impedance allows you to use smaller timing capacitors than you would normally use on the non-CMOS NE555. This results in greater accuracy in time delays and oscillations. Lower power consumption across the full range of power supply voltages is the best feature for battery-operated applications like this.

Mechanical Assembly

NOTE: Most instructions assume the six pawn version with the LED holder and optical fiber cable. For the four pawn version, substitute the regular LED and ignore instructions related to the optical fiber option.

Insert the magnets in the pre-drilled base of each pawn. If you drill the pawn holes too deeply, fill them in with wood putty — until the magnets are flush with the outside surface.

Place a felt pad over each magnet to conceal it to help preserve the trick.

Temporarily remove the brass screws and nuts from the rear hinges.

Assemble the three wooden pieces with the six Escutcheon pins, small brads, or nails provided. Ensure that the piece with the recessed drilled hole faces to the outside and appears on the right.

Attach and shrink the 1/8" shrink tubing at one end of the optical cable. Cut at 90 degrees the combined optical cable and shrink tubing with a blade as close to the end as practical. Insert the shrink tubing end through the narrow side of the (Nylon) shoulder washer (see Figure 10) and make it flush with the wider side.

Insert the narrow side of the plastic (Nylon) shoulder washer (molded Nylon insulator) into the piece with the 1/4" recessed hole (to the right) until the washer is flush with the wooden surface. This completes the cradle.

Insert the cradle into the box, again, with the recessed hole or shoulder washer to the right. The optical cable and hole should line up with the hole in the side of the box. You can test this by pointing the free end of the optical cable at a light source and observing the light in the hole from the outside of the box.

Replace the brass screws and nuts you initially removed from the back hinges. It is best to hold the nut and turn the screw from the back of the box with a screwdriver, advancing the screw within and securing the nut. If holding the nut proves difficult, you may wish to allow the shrink tubing to hold it as you start the nut and get a turn or so going.

Remove the paper Alignment pattern from the box's lid if you have a kit. (Align this pattern with the acrylic sheet using the four corner holes as reference points and temporarily tape into place.)

The Alignment pattern inside the box's lid has three sets of intersecting circles. The largest represents the peel-off adhesive backed paper patterns used to conceal the electronics below. The next two sized holes represent the plastic hardware spacers through which you pass the sensors so their respective magnets will be able to activate only that sensor. There are some crosshairs that indicate where the active sensing area of the Hall effect sensors' facades will reside once bent over. Bend all sensors toward the middle in all instances to intersect the crosshairs.

Precautionary Assembly Tips

The following tips are from our empirical observations after assembling this DIY project's PCB numerous times.

• *Tilt Sensor Leads*. Leave these leads long so that you can purposely short them during test. This alleviates your concern about tilting the PCB in just the right way to power the project.

• *Save Your Spent Leads*. Some of the resistors serve as bridges where resistors R10, R20, and R21 should have gone. As the design evolved, it used a different voltage regulator of just 3.3 volts, so there was no longer a need for a series limiting resistor (R10). Now you bridge it with a spent clipped resistor lead. Components R20 and R21 are labeled as resistors, but are actually jumpers that are used for the four pawn version. These two jumpers are not included in the six pawn version. You use two pull-down resistors, R24 and R25, to disable the circuit required in the four pawn version.

• *Power Component Leads*. Leave these long. They will later serve as convenient "hooks" for a probe when you test the project's power supply.

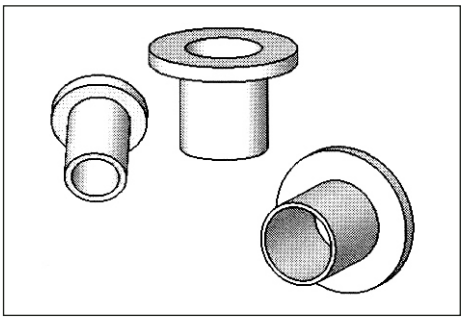
• *Install the Battery Holder and Transformer Last*. We suggest you do this, which will require you to use clip leads and an external DC power supply during testing of the project's power supply section. If you don't have a DC power supply on your bench, use clip leads to your nine volt battery.

• *Installing Capacitors*. Exercise care here by bending them over affording clearance when you solder the Hall effect sensor leads. This assumes you install the capacitors first.

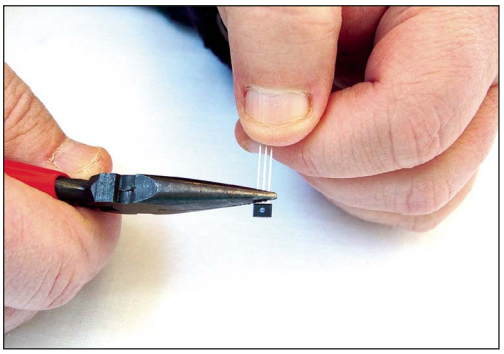
• *Installing Resistors*. We highly recommend you check all resistors with a DMM since there are some 1% resistors with five stripes; the extra stripe is a reliability code and this can be confusing.

• *Look for Shorted Adjacent Pins*. Double-check the adjacent pins on the Hall effect sensors and voltage regulator for solder bridges. We suggest using the continuity beeper found on most DMMs to check their very closely spaced 50 mil leads.

• *Hall effect Sensors' Crucial Lead*



■ FIGURE 10. The nylon extended shaft shoulder washer.

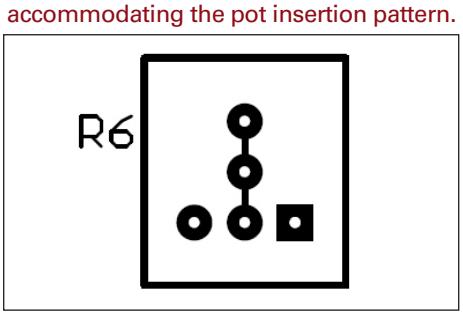


■ FIGURE 11. The proper bending technique for the sensors' bodies — push down on the leads and hold them fast with pliers, protecting the leads from strain as they enter the sensors' bodies.

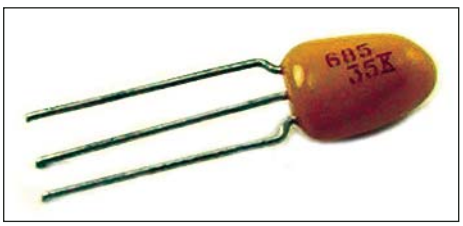
Lengths. The sensors must intersect the crosshairs in the paper pattern for proper alignment directly below the magnets for optimum effectiveness and reliability. We suggest you bend the sensor body so it just slightly overlaps the Nylon spacers' lip (see Figure 11). Ensure that it faces so the nomenclature on the IC points upward (see Figure 4 again).

• *Hall effect Sensor Handling*. These ICs have extremely brittle, unforgiving leads. If you incorrectly bend a sensor with the façade pointing down, you'll need to re-bend it. After several bends, its brittleness can cause the leads to snap off. Properly bending and soldering these closely spaced sensor leads is by far the most difficult part of assembling this project. We averaged two solder bridges per every six sensors installed, and we are both experienced electrical engineers.

■ FIGURE 12. A PCB multiple footprint accommodating the pot insertion pattern.



■ FIGURE 13. A three-lead, foolproof insertion, polarized capacitor.



Electrical Assembly and Testing

Both versions of the available kits have two pots: a 10K and a 100K pot. Due to multiple sources of supply, these components assume different shapes and footprints; therefore, the PCB accommodates this by a universal footprint that accepts a variety of different pots (see Figure 12). This is also true with C1, the 6.8 µF 555 timer IC's timing capacitor, which has three leads (see Figure 13).

This beneficial feature may seem strange to you. The positive terminal goes in the center hole. The two outer holes are for the negative terminals, so it is impossible to install this polarized capacitor backwards.

On later versions of the kits, we use an ordinary two lead polarized 6.8 µF capacitor since we only had a limited number of these foolproof-insertion capacitors. The PCB also accommodates 0.01 µF or 0.02 µF capacitors with 0.2", as well as 0.25" lead spacings (see Figure 14). We discovered after experimenting and running tests that the Hall effect sensors recommended output capacitors may be either a 0.01 µF or 0.02 µF capacitor.

Electrical Assembly Procedure

Assemble the power supplies: Tilt the switch circuit to connect the 9V battery; the 3.33 volt regulator circuit (because sensors cannot handle all 9V) runs the sensors, logic, and LMC 555 oscillators. Bend the tilt sensor leads so they do not lay flat to the surface below. This enables the internal ball bearing to roll away from the contacts. This opens the circuit and reliably turns the circuit off when you tilt the box on its back hinges (see Figure 31 in last month's issue to better visualize how the tilt sensor actually works).

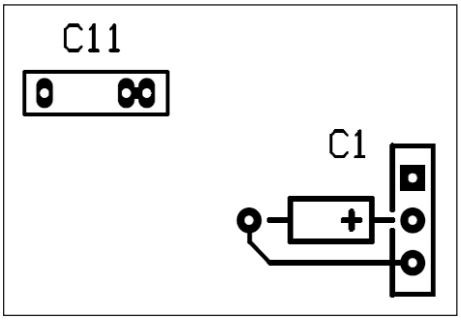
Connect the 9 VDC power supply or battery to battery inputs and measure the output of the voltage regulator. The nominal value is 3.33 VDC. The worst-case range is 3.16 VDC to 3.50 VDC. The selected values of the two programming resistors ensure they sink enough current to exceed the minimum output current required by the voltage regulator IC.

Assemble the LED driver circuit: R13, LED, Q1, jumper (R10, an electrical short in the form of a simple piece of wire or clipped component lead), R8, and pot R9. For the six pawn kit version, when you mount the LED/optical fiber holder, screw it in first using the plastic hardware supplied. Ensure the two plastic alignment nibs (positioning/seating feet) are properly seated in the two holes on the PCB right behind the collet. This allows you to solder it without fear of slippage or improper positioning.

For the four pawn version, make sure the cathode lead goes in the hole marked "K" and that the anode lead goes in the hole marked "A." The typical LED has a shorter lead and a flat on the cathode side of the lens. Failure to insert a bridge or wire (short) where R10 goes will cause the kit to function improperly.

Assemble the 1 Hz oscillator (U6 circuit). Test with a DMM/frequency counter or use a test lead to jumper a 1 Hz oscillator to LED driver (either terminal of R8) to verify its operation.

Assemble the 60 Hz oscillator (U5 circuit). Test with a DMM/frequency counter or jumper a 60 Hz



■ FIGURE 14. The PCB layout pattern showing built-in accommodation for various capacitor spacings.

oscillator to LED driver to verify its operation. It will look like it is continuously on with the LED driver; it should be flashing at about 60 Hz.

Complete the assembly of the sensor circuits by adding 0.1 µF, 0.01 µF, or 0.02 µF, the sensors, NOR gates (U7, and U15 for the six pawn version), and pull-up resistors (R1-R4, R22, and R23). It works best to install the sensors last. First bend the sensor leads at a 90-degree angle (see Figure 10 again). Insert the sensor leads into a 1/4" spacer.

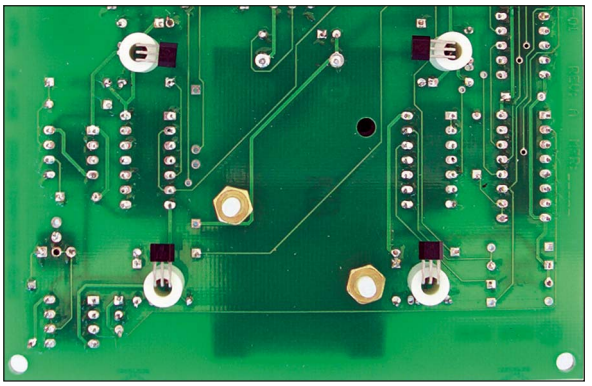
This is an absolute must and is vitally crucial to ensure good reliable operation. Insert a Hall effect sensor into the appropriate white plastic spacer and bend the leads over with the sensor's nomenclature side face up so that the sensor's body just barely overlaps the edge of the spacer. This ensures a proper length that the sensor will jut out to coincide with the maximum magnetic field from the magnet directly above it.

Next insert the leads into the corresponding pads on the underside of the PCB (the side without a silkscreen). The spacers will be near the capacitor and the pull-up resistor leads solder pads, so it is easier to solder these components in place before installing the sensor. If you install each sensor correctly, it will "point" to the center of the PCB (see Figure 15). The silkscreen outline for the sensor location has a chamfered corner to denote pin 1 (see Figure 16). When you look at the face of the sensor with printing and with the leads pointed down, pin 1 is on the left, pin 2 is the center pin, and pin 3 is the pin on the right (see Figure 17).

Test each sensor circuit at the output (pin 3) with a DMM or use a test lead to jumper the output (pin 3) to the LED driver. The presence of a sufficiently strong magnetic field with the close proximity of one of your assembled pawns makes the output of the sensor short to ground. The LED remains on until the sensor detects the magnet. When the sensor detects the magnet, the output goes low, turning off the LED.

Assemble logic (U1, U2, U3, and U4), pull-up resistors (R11), and pull-down resistors (R15, R24, R25). Test this by connecting the 9 VDC power supply and observing the LED. It should be on for three counts at the start of the sequence and one count for each sensor location activated.

■ FIGURE 15. The Hall effect sensors all properly pointing inward toward the PCB's center.



You can accomplish this by holding one magnet close to each sensor and observing the pulse timing change. There should be one long pulse for the marker pulse and one short pulse for the detected magnet. The short pulse time relative to the long pulse will change depending upon which sensor you activate.

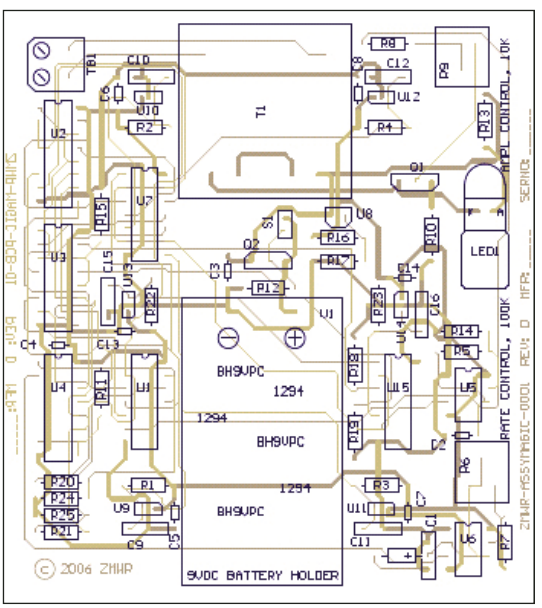
Adding the Tingling Circuit (T1 and TB1)

Take the two wires (as in the kit) and unscrew the terminal block's terminals. Now slide the pre-tinned bare ends of the wires underneath each terminal. Tighten the screws so the terminal block securely holds the wires. There are two brass screws on the two back hinges. Unscrew these and temporarily remove their nuts to slip the lug over the screw. Take the other end of each wire with the #6 lugs. Attach the nuts back onto these two screws. These are for the transformer's output, and provide the tingling sensation for missing pawn detection by the tactile method.

Now you can push-fit the top of the terminal block onto the two pins that you soldered onto the PC board (see Figure 18).

The transformer's output attaches to the terminal block. It holds two conductors or wires. Each wire needs a #6 lug on one end and a pre-tinned bare wire on the other end to prevent corrosion. Pre-tinning is applying solder to metallic parts (usually the ends of wires) to improve their soldering ability during assembly. Most often you do this using a solder pot (as we have done for you in the kit). The terminal block is a Eurostyle 5 mm (.197") pin-to-pin spacing model. It uses 0.05" round pins instead of 0.025" square pins like wire-wrapping terminals have.

■ FIGURE 16. Here is the PCB component outline drawing/silkscreened pattern.

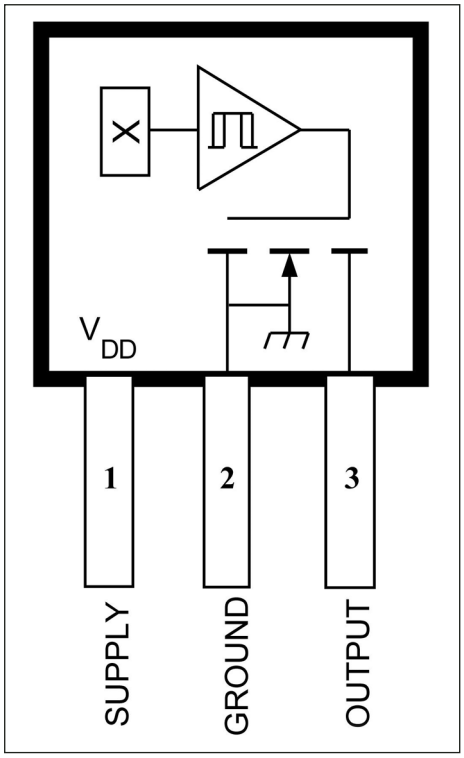


A Two-Part Terminal Block

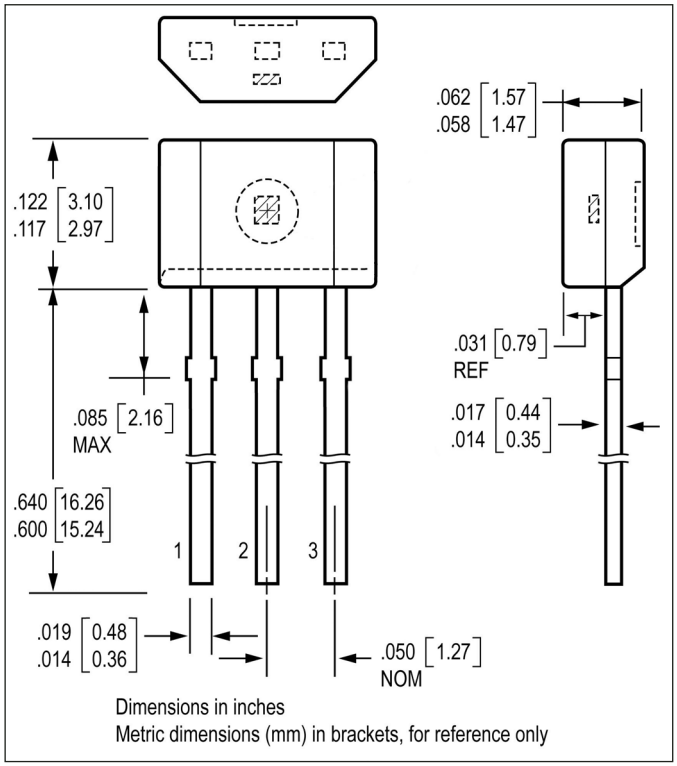
The terminal block's upper portion slides over these two pins. This conveniently allows you to slide off the two wires which — after you unscrew the collet of the LED on the enhanced version — allow you to temporarily remove the PCB from the base. This might prove handy when you change the nine volt batteries.

More Foolproof Instructions

It does not matter which way you attach the upper portion of the termi-



■ FIGURE 17a. The Hall effect sensor IC's pin assignment. Artwork courtesy of Allegro Microsystems.



■ FIGURE 17b. The Hall effect sensor IC's outline drawing. Artwork courtesy of Allegro Microsystems.

nal block since it carries AC (has no polarity) to the hinges for the tingling or tactile missing pawn detection method. If it seems strange to you that this is AC in a battery powered project, remember, AC pulses the transformer's input and it will not pass DC.

Turn the 10K pot (R9) to the middle of its range. One side of the pot is shorted to the tap, so you increase or decrease the resistance in the circuit when you adjust the pot. You can test the circuit with the DMM or touch it with two fingers of one hand after attaching the wires to the hinges. You should get a strong tingle in your fingers each time the test LED illuminates.

The DMM will measure a large voltage and/or the same frequency as the 60 Hz oscillator. If you prefer a less intense tingle, you can increase the value of the pot to further limit the current into the base of Q1. Conversely, decreasing the value of the pot yields a more intense tingle.

Permanently install the battery holder with Nylon screws and nuts and solder the pins to the board.

Once you assemble and test the PCB, insert the four wood screws (one in each corner of the top wooden panel with the PCB assembly), the longer spacers, and the acrylic sheet aligned

Hall Effect IC and Sensor Manufacturers

■ *Allegro Microsystems* — {Hall effect sensors}; 115 Northeast Cutoff, Worcester, MA 01606; (508) 853-5000.

■ *American Electronic Components, Inc.* — {Hall effect sensors} 1101 Lafayette Street, Elkhart, IN 46516; (574) 295-6330; Toll Free: (888) 847-6552.

■ *Amploc* — {Hall effect current sensors} P.O. Box 152, Goleta, CA 93116; (805) 964-9119.

■ *F.W. Bell/Bell Technologies, Inc.* — {Hall effect sensors} A Division of Sypris Test & Measurement; 6120 Hanging Moss Road, Orlando, FL 32807; (407) 678-6900; Toll Free: (800) 775-2550; Fax: (407) 678-0578.

■ *Cherry Electrical Products* — {Hall effect sensors} 11200 88th Avenue, Pleasant Prairie, WI 53158; (262) 942-6500.

■ *CR Magnetics, Inc.* — {DIN rail or panel mount DC Hall effect current transducers modules} 3500 Scarlet Oak Blvd, St. Louis, MO 63122; (636) 343-8518; Fax: (636) 343-5119; Email: sales@crmagnetics.com.

■ *Honeywell* — {Hall effect sensors} 101 Columbia Road, Morristown, NJ 07962; (973) 455-2000; Fax: (973) 455-4807. This link describes an excellent book on the subject published by Honeywell **www.sensorsportal.com/HTML/BOOKSTORE/Hall_Effect_Sensors.htm**.

■ *Infineon* — {High sensitivity Hall effect sensors} Service Center: (866) 951-9519.

■ *Melexis Microelectronic Integrated Systems* — {Hall effect sensors} 41 Locke Road, Concord, NH 03301; (603) 223-2362; Fax: (603) 223-9614.

■ *Micronas Intermetall* — {Hall effect sensors} Hans-Bunte-Strasse 19, P.O. Box 840, D-79108 Freiburg, Germany; 49-761-517-0; Fax: 49-761-517-2174; **www.intermetall.de**.

■ *Motion Sensors, Inc. (MSI)* — {Hall effect sensors} 786 Pitts Chapel Rd., Elizabeth City, NC 27909; (252) 331-2080; Fax: (252) 331-1666; Email: info@motionsensors.com.

■ *Optek, Inc.* — {Hall effect sensors} North American Headquarters Mexico and The Americas, 1645 Wallace Drive, Carrollton, TX 75006; (972) 323-2200; Toll Free: (800) 341-4747; Fax: (972) 323-2396; Email: sensors@optekinc.com.

■ *Xensor Corporation* — (Hall effect sensors — single, dual, and triple) 530 South Henderson Road, Suite A, King of Prussia, PA 19406; **www.xensor.com**.

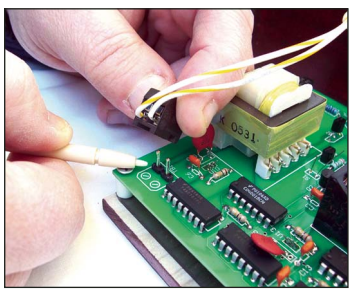
and sandwiched between. Use a 5/16″ spacer and a #4 by 3/4″ wood screw at each corner. Attach wires to the terminal block and hinge screws if you have not already done so.

Insert the optical fiber into the heat shrink at one end and shrink the tubing. You can easily shrink it with a hair dryer, but do not touch it with a soldering iron! This can damage the optical fiber. Use another piece of shrink tubing around the tilt sensor so that it does not inadvertently short to anything metallic.

Cut a small piece of the end with a razor knife at 90 degrees to get a clean end for maximum light output. Insert the heat-shrunk end through the wooden support on the side of the box with the corresponding hole. There will be a 1/4″ or 3/8″ sunken recess about 0.05 inches deep on the side which faces the interior of the box. Insert the optical fiber and heat shrink through the molded Nylon insulator so that the "washer" side is nearest and flush with the end of the optical fiber. Insert the molded Nylon insulator, with the fiber running through it into the 9/64″ hole in the wooden support (see Figure 19). Insert the wooden supports into the box. This should line up the optical fiber with the hole in the box's side.

Attach the terminal block to the PCB assembly. For the six pawn version, attach the optical fiber to the PCB. Insert the 9 VDC battery into its holder. Install this assembly with the PCB component side down and the battery holder to the right.

■ FIGURE 18. Installing the wires onto the terminal block.

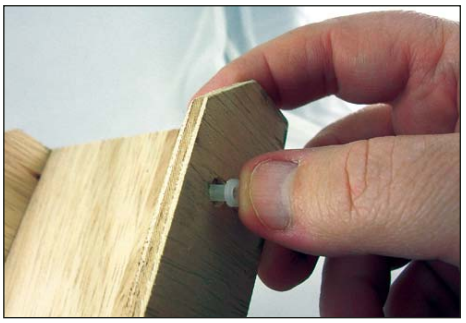


ACKNOWLEDGEMENTS

■ We wish to thank Stephanie Fennelly of Allegro Microsystems for supplying us numerous pieces of high quality line art and for having a member of the Allegro technical staff read this article to ensure its technical accuracy.

Test the assembly by installing the six pawns into their respective holes. You should observe seven pulses at the end of the optical fiber through the pinhole and feel the corresponding tingles when you touch the hinge. You should observe one long and six short pulse durations.

We hope you enjoy the construction of the Magic Box and are able to spend many hours mystifying and bewildering family and friends. **NV**



■ FIGURE 19. Inserting the nylon extended shaft shoulder washer into the cradle's right side member.

ITEM	DESCRIPTION
Passives (all resistors are 1/4 watt 5% unless stated otherwise)	
❑ R1, R4, R7, R11, R12, R15, R18, R19, R22-R25	100K
❑ R5	120K
❑ R6	100K rate control pot (various suppliers)
❑ R8, R13	100Ω
❑ R9	10K amplitude control pot (various suppliers)
❑ R10, R20, R21	Onboard jumpers
❑ R14	10K
❑ R16	215Ω, 1%
❑ R17	357Ω, 1%
❑ C1	6.8 µF tantalum polarized capacitor
❑ C2-C8, C13, C14	0.1 µF capacitor 0.25″ spacing (various suppliers)
❑ C9-C12, C15, C16	0.01 or 0.02 µF capacitor 0.2 or 0.25″ spacing (various suppliers)
Semiconductors	
❑ U1	74AC00
❑ U2, U3	74AC151
❑ U4	74AC161
❑ U7, U15	CD4001B
❑ U5, U6	LMC555CN
❑ U8	LM317LZ
❑ U9, U10-U14	A3214LUA SOT package (Digi-Key P/N A3214LUA-ND)
❑ LED 1	LEDXMTR blue LED or Industrial Fiber Optics P/N IF-E96 (Digi-Key P/N FB128-ND)
❑ Q1, Q2	PN2222A
Misc.	
❑ S1	SPST tilt switch, metal case two-lead (Electronix Express Rollerball P/N 1700TLRB)
❑T	2 VA CT transformer, like Tamura SB2812-1204 (Digi-Key P/N MT7249-ND)
❑TB1	2 pin .197″ (5mm) Euro terminal block (Jameco P/N 164793)
❑Two #6 stud ring terminals, 22-16 AWG	(Jameco P/N 103684)
❑ 9 VDC battery holder	(Digi-Key P/N BH9V-PC-ND)
❑ Six or four pawns with six or four magnets and felt self adhesive pads	
❑ Metallic hardware	
❑ 19 pieces of plastic hardware	

Notes

For the six pawn enhanced version, delete R18-R21. For the basic four pawn version, delete C13-C16, R22-R25, and U13-U15. Send a personal check, cashier's check, or money order. International orders also accepted. Address it to Vaughn Martin, Zonemasters, 106 Shadowood Drive, Warner Robins, GA 31088. The price of the six pawn kit is $39.95 plus $5 shipping and the four pawn kit is $33.50 plus $5 shipping. The wooden box is $12 postage paid and the PC board is $12.50 postage paid; **www.zonemasterskits.com**.

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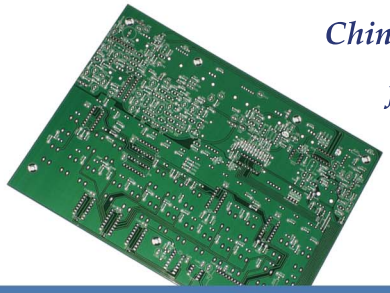

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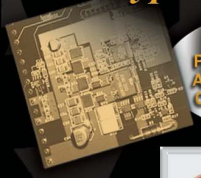
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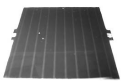

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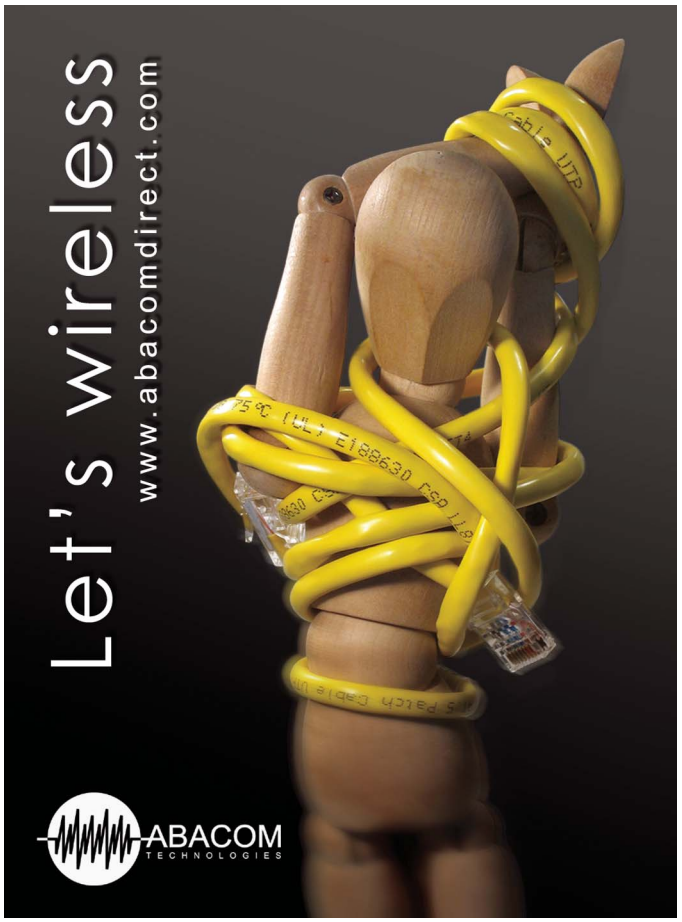

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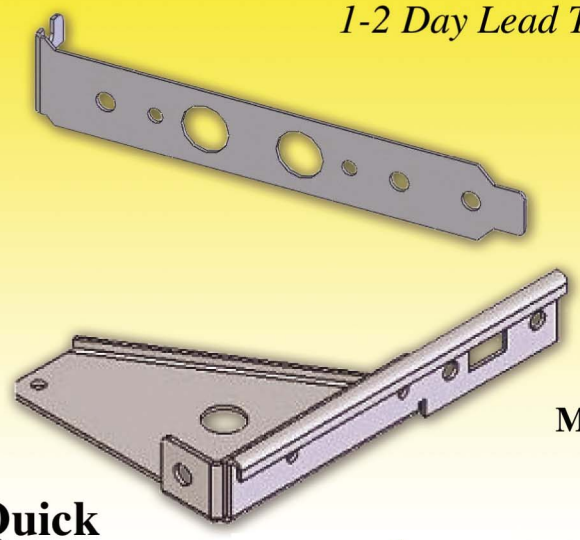

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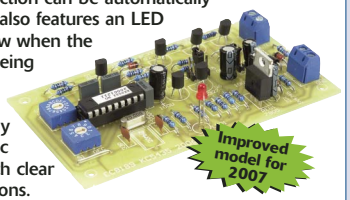

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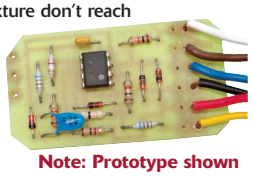
This simple kit enables you to defeat the factory fuel cut signal from your car's ECU and allows your turbo charger to go beyond the typical 15-17psi factory boost limit. - Note: Care should be taken to ensure that the boost level and fuel mixture don't reach unsafe levels.

- Kit supplied with PCB, and all electronic components.



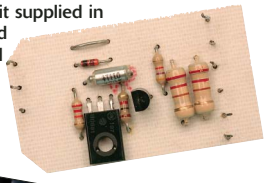
Note: Prototype shown

Variable Boost Kit for Turbochargers

KC-5438 $11.75 + post & packing

It's a very simple circuit with only a few components to modify the factory boost levels. It works by intercepting the boost signal from the car's engine management computer and modifying the duty cycle of the solenoid signal. Kit supplied in short form with PCB and overlay, and all specified electronic components.

Note: Prototype shown



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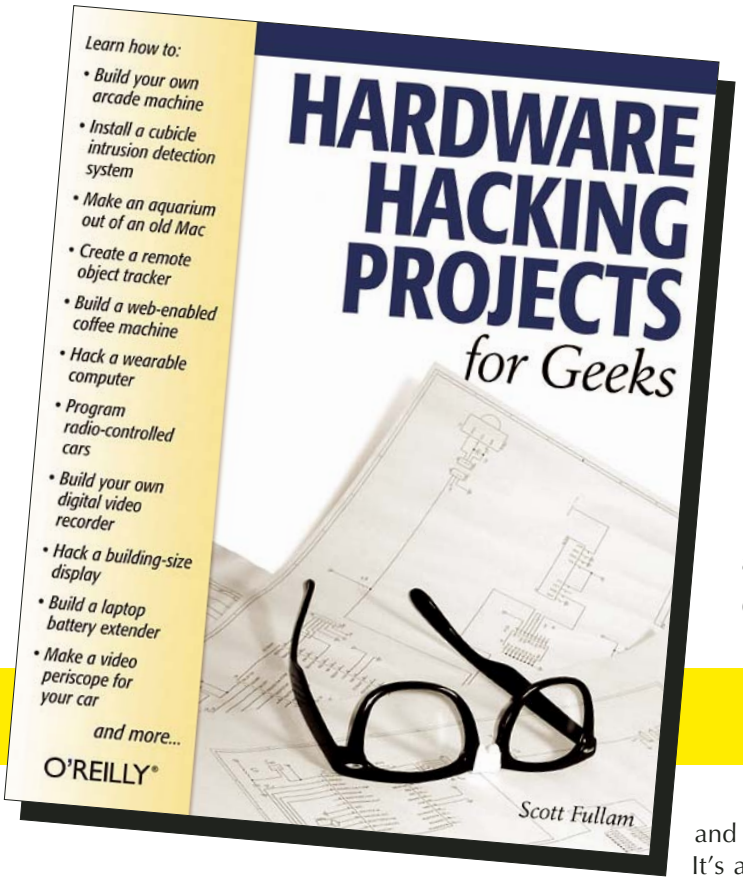


HACKING THROUGH

Hardware Hacking Projects for Geeks

Scott Fullam wants to hack into your computer. Your satellite dish. And even your coffeepot and toaster. Actually, it's worse — the former Apple employee wants you to do his dirty work for him.

by Edward B. Driscoll, Jr.

Fullam is the author of *Hardware Hacking Projects For Geeks*, an O'Reilly & Associates release (available at **www.oreilly.com/catalog/hardwarehks**, **Amazon.com**, and retail booksellers). It's a book that does a great job of teaching basic electronics skills through a variety of projects that can be created as a reader's skills progress. The first half of the book contains some fun but smaller projects, such as building a battery pack to extend the life of a laptop, an aquarium inside a Mac computer, and transforming a Primestar satellite TV dish into an 802.11b wireless Internet extender.

In the second part of the book, the projects get more advanced, but they build on the basics taught in the first half. Throughout the book, there are little thermometer-shaped graphs that show what's involved in a project and how much money it will cost.

The second half of the book has some great projects: a way to fill the windows of a multi-story office building with lights and create a Goodyear blimp-style display that can be remotely controlled; building a home arcade machine (complete with standup case); wearable computers; radio controlled cars that play laser tag; a toaster that will burn user-programmed words onto a piece of toast; and a great in-joke for Internet old-timers — the Internet coffeemaker. It's a homage to a project by Cambridge students in the late 1980s, when they mated a video cam with a coffeepot, to remotely see via the Internet if coffee was done.

"I really was sort-of inspired by my own experience. I learned by taking things apart, I learned by building things," Fullam explains. "I didn't always understand what I was doing at the time. But the process you go through to do that thing, you pick up the skills; you gain an understanding of that object and of those skills. So that's really how I tried to structure the book — it's learning by doing. It's sort-of part cookbook, part tutorial, and part 'hey, this is a great jumping off point, and you can use your skills to build some new stuff.'"

Every project contains a complete parts list with information on where to buy the parts, and the book is thoroughly illustrated with black and white photos, showing both the completed project, and many of the steps to get it to that point. There are also plenty of schematics and diagrams. "I'm a very visual person, so those things at least helped me, and I thought they would help others, as well," Fullam says. "I really tried to take a lot of the work out it, so that you could build the project as listed by following the instructions."

Meet the Hacker

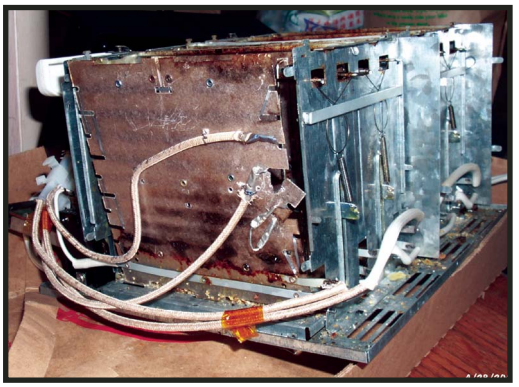
Fullam is a 30-something-year-old computer consultant who resides in Menlo Park, CA — not all that far actually, from where another famous hacker, Steve Wozniak, designed what would become the Apple computer. Fullam has been an inveterate tinkerer ever since he was 10 years old living in upstate New York and hacking his RadioShack 100-in-1 electronics kit to build an intruder alarm to keep his sister out of his room.

Fullam eventually attended MIT, where he earned bachelors and masters degrees in electrical engineering and computer science. While an undergraduate there, to help see if there was any hot water available in his dorm during the brutal New England winters, he built a detection system so that he could see if the community shower was in use.

After graduating from MIT, Fullam designed children's toys in New York,

Continued on next page

Burning the Toast



So how did Fullam end up writing a book about hacking? A few years ago, he was approached by a friend of his from grad school who was working for O'Reilly. "And they were looking to expand their repertoire of books; push themselves in an area that they maybe hadn't approached before. My associate, when he thought about hardware hackers, mine was the first name that popped into his head!

"We saw an open forum as far as what we could do, and I just decided to pick out some work and projects that I had done before, even some new ones, and look around in the community and see what people had done that I thought was interesting." Fullam then documented both those outside hacks, as well as his own projects "to make them readable, to make them understandable, and to make them work."

O'Reilly's art department added the cherry on the cake with the book's cover, which features the classic black horn rim Woody Allen glasses long associated (rightly or wrongly) with computer geeks, held together at the bridge with white tape, on top of a set of schematics. The book begins with a very ominous disclaimer that releases O'Reilly from any damages resultant from hacks gone awry. But Fullam says if readers follow the instructions carefully, they aren't likely to blow themselves up. "They might burn their toast a little bit, but that's about it." **NV**

and built close to 50 prototypes in two years, including "Teen Talk Barbie." He then went to work at Apple Computer in the Advanced Technology Group designing digital still cameras. He holds 15 patents, several of them for his work in bringing some of the first digital cameras to the marketplace.

Some of Fullam's other patents stem from his work with PocketScience, which he co-founded in 1995. PocketScience (now called PocketMail) develops mobile e-mail communications products and services. As the chief technology officer, Fullam personally developed all of the algorithms for the company's products.

Fullam now works as an independent consultant assisting consumer electronic companies. Not surprisingly, he often takes his own consumer electronics products apart and tinkers with their features. In a profile of Fullam, the *San Jose Mercury News* described his garage as resembling a "Hollywood movie-set version of a Silicon Valley garage, bulging from floor to ceiling with disemboweled gadgetry."

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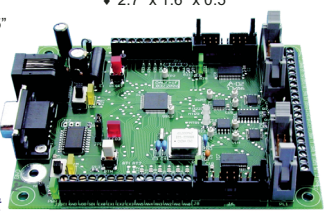

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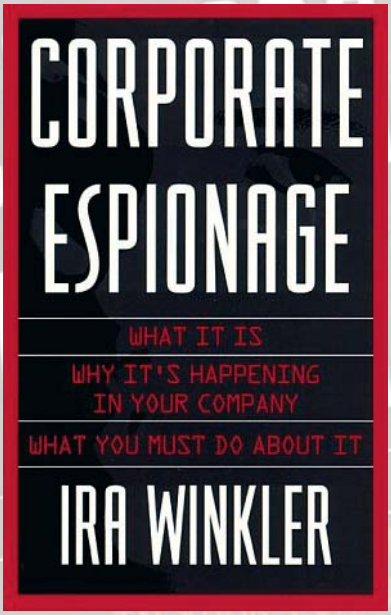


Going Security Geek on Penetration Tests With IRA WINKLER

by David Geer

Q: When is hacking legal?

A: When the company being hacked hires the hacker.

These hacks — called penetration tests — are done on purpose to show companies how much they stand to lose if they don't patch their security holes.

Penetration tests are used to try to compromise the security of computer systems to make sure they are not vulnerable. This is a good thing, done by good guys, called White Hat Hackers.

There are many reasons to do a pen test, including:

- To see how a malicious party may attack ... and how far they would get.
- To see if the company can detect the attacks.
- To identify as many vulnerabilities as possible.
- To get the attention of management.

Taken (from "Ideal Goals of a Pen Test," presentation slide by Ira Winkler, president and CEO, the Internet Security Advisors Group (ISAG), "an international information security firm specializing in mass marketing product security offerings through channel partners.")

Pen tests use simulated corporate espionage, social engineering, physical access to computers, and remote hacking. Pen tests often require a combination of two or more of these elements. With the help of Mr. Winkler, we'll cover pen tests and protections against hacking.

Who is Ira Winkler? He's a straight shooter and someone who can speak with authority on the subject. Ira is a former software tester, NSA guru, and now confirmed good guy hacker. Dubbed a modern day James Bond by the media, Ira has a history of discovering how information systems are hacked.

Mr. Winkler has been hired to hack into many Fortune 500 companies. He has done so, handing them back anything from access to $1 billion in assets to plans for a nuclear reactor. All this is done to point out the companies' network vulnerabilities.

The author of *Corporate Espionage: What It Is, Why It Is Happening in Your Company, What You Must Do About It*, Ira advises the FBI and other top dog organizations. They listen; so should you.

Espionage Simulations, Social Engineering, and Physical Access

Ira usually starts with corporate espionage, in an effort to pull together the non-technical pieces of the puzzle. This brings the system or systems he wants to penetrate out into the open. Sometimes, Ira uses social engineering — a form of social interaction.

Social engineering lets you gather bits of information, compiling what you need until you have the whole picture. In this case, the information is how to access the company's computers. Social engineering can be done in person, but is usually done over the phone.

For example, Ira once called a bank and took control of it in three days. The information he used to accomplish this was gained entirely over the phone — information about computer access. You may have seen these kinds of calls portrayed in movies or TV, usually being used by private detectives. Deceit and misrepresentation are definitely on the menu.

In the following detailed example, espionage, social engineering, and physical access were all used.

"I stole the designs for a nuclear reactor by saying I was doing a quick security audit. I walked over to the people who put together the design plans for a proposal that was going to be presented to the people buying the nuclear reactor. I said I just needed to

Photos courtesy of Ira Winkler.

type a couple of quick commands. I got the Internet protocol (IP) addresses of the computer that stored that information," says Winkler.

In another pen test, Mr. Winkler stole a $1 billion in sensitive information in just a day and a half after getting himself hired as a temporary employee. The list of cases is long and distinguished.

The Technical Side of Pen Tests

There are only two ways to hack. One is to exploit weaknesses built into operating systems and software. The other is to exploit the human error that shows up in the form of administrator's or user's configuration errors. These are things like username and password selections or permissions for who can access which computers or data.

As Ira put it in a presentation, "All software has bugs; some bugs are security related." Bugs can be exploited to gain privileges on a system. Bugs also come in the form of information leakage, which can be tapped to steal critical information.

Even Unix and Linux systems can be broken (hacked). "The way you take advantage is to go to a website like **www.antionline.com/index.php** and just download the exploits. Sadly, it's that easy. Then you try to run them against individual systems or IP address ranges; frequently you'll get in," explains Winkler.

Another method is to ping IP addresses in a pingable address range. IP addresses and ranges are numbers in patterns like 255.255.255.104 through 255.255.255.111. Then, if you identify servers in that range, you can look to see if the servers have exported hard drives. For example, an administrator may have used a tool, like NFS Manager, to export a hard drive. If the setting was to export it to the world, then anyone could mount that drive from an Internet connection. It's even easier if no permissions have been set.

User ID (UID) and Password (PW) guessing are also easy, due to nonrandom or default UID and PW selections. According to Ira, "most of the time, the administrator password on Windows systems is the same as the password for the administrator accounts. Just type in "administrator," "administrator," and you'll gain access frequently."

Here's another example from Ira on password guessing: "I always tell the story where I knew this woman and her user id was "Kirk" and I was just joking around with her that her password was "captain." She just looked at me in horror, saying, 'how do you know what my password is?'" People tend to think in associative ways. If you start where they start, you'll often come up with the same choices.

Other common holes include the default Login/Password (LP) accounts on Unix systems. It's called LP because the default login is "login" and the default password is "password." Amazingly enough, these are often not changed. "If people don't administer their systems properly, it's really easy to take them over."

More Examples — Oldies but Goodies

"This is an old one, but I prefer older ones because, hopefully, they are not as vulnerable now," Winkler elaborates. This one exploits early versions of the Windows 95 operating system. With these older versions, the password was stored in clear text, right out in the open in the Windows registry file.

With physical access, you only had to wait until someone was away from his or her computer and go into his or her Windows registry file to see his or her password. You could also take a look using the Internet, if the user had shared their hard drive with the world.

Each computer type and operating system has its own vulnerabilities. "For the Virtual Addressing Extended (VAX) computers, the Virtual Memory System (VMS) systems, frequently you could walk over to a VMS computer and type in the user id 'field' and the password 'service' and that would give you administrative privileges," says Winkler.

There are many examples for exploiting default accounts. You can get all the systems on a network by using the Unix "hosts" command. With the right attributes, you can type in "hosts" at "company.com" [using

Tips From Ira Winkler for Hardening Your Home Network

1: All systems should run anti-virus software. Enable the feature to automatically check for updates.

2: Check for backups and make your own backups on a regular basis.

3: "Personal [software] firewalls are a must. Some DSL routers include firewall functionality. Some attacks can tunnel through these. Even if you have a DSL router that has firewall functionality, you have to make sure it's updated regularly. Make sure your personal firewall is on each computer system. Attacks can make it through a firewall. You don't want to have your firewall as a single point of failure," cautions Winkler.

4: Have a hardware firewall between the Internet connection and your internal network.

5: Stay away from malicious websites. Stay away from pornography sites because those tend to install back doors and key capture mechanisms. [Try using a hosts file, as at **www.mvps.org/winhelp2002/hosts.htm**.]

6: Periodically check systems to see that firewalls are up and running.

Ira Winkler on Monkey Business

Hacking is simple. Any monkey can hack a computer given the right training. Hacking is simply breaking into a computer. Anybody can break into a computer; protecting it is the hard part.

People learn how to break into their own systems; that's okay, but it's like a parlor trick. What's going to teach you more is learning how to protect them. If you really want to know the inner workings of your systems, you need to understand your operating systems and understand how the OS can be compromised.

Read about how to prevent the vulnerabilities. People look at hackers as super geniuses. They are not super geniuses; they are just using the slight of hand that anyone can use if they, "pay the money to buy the magic trick in the store," says Winkler.

You need more sophistication to know how to protect yourself. "You need no sophistication to figure out how to break in. I went into a company once and 70% of the passwords were the same as the user id. I needed zero knowledge to break into that," commented Mr. Winkler.

Breaking into the Government

Penetration test performed by colleague
Thought their mainframe was a fortress
Thought even though they were on the Internet, they were safe

Results

Compromised highly sensitive systems
Went undetected
Less than 3 days

These are the results of the Pen Test.

the actual company name], "and, if the firewall and network aren't set up properly, you can map the network of your potential target," Winkler details.

How to Secure Networks and Pass Pen Tests

Use strong passwords and change them often. You can start by following Microsoft's instructions for creating strong passwords, found at **www.microsoft.com/security/articles/password.asp**. Changing your password weekly can help prevent a hacker who sniffed your password (See PW Sniffer Flow Chart) from having a chance to use it. This helps guard against one of the primary means of hacking — attacking configuration weaknesses that are due to human error.

You can also harden your operating system against attacks and

Describes Pen Test involving Password Sniffing.

intrusions. Check the Center for Internet Security at **www.cisecurity.org** where you'll find links to "benchmarks" (detailed hardening configuration instructions) in the left pane. Additional hardening instructions are available at the same location.

"The concept of hardening the systems means you are taking the systems as they come 'out of the box,' which are, unfortunately, pretty much insecure, and just turning features on and off," Winkler explains. Turning up the right features secures systems against known hacking methods.

If you use Windows, you should also use the Windows Updates tool under the start menu. It's just a link that takes you to Microsoft, where they scan your computer for needed updates. You can bypass the scan and select the updates yourself.

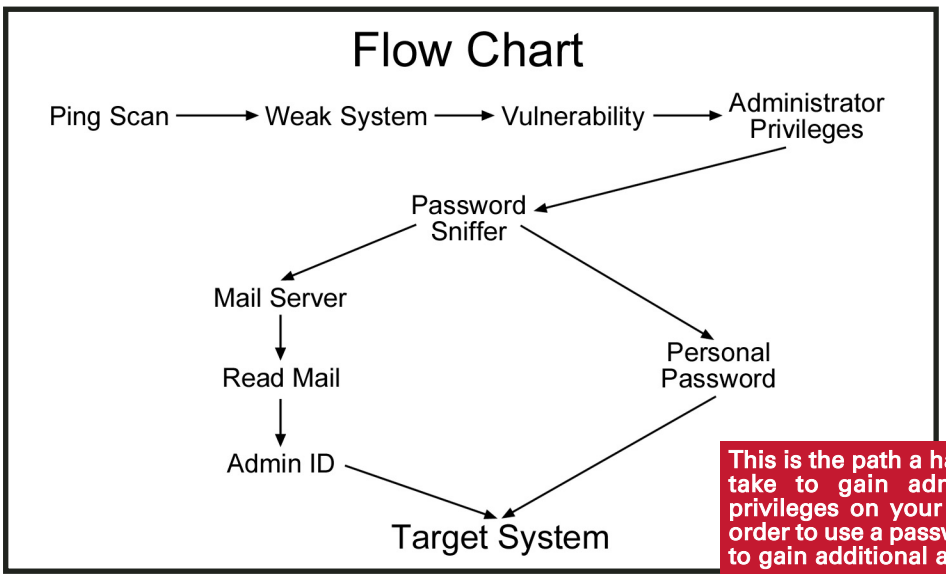
You should check with your software vendors to get their updates. They also have bulletins for their software packages. These notify you of new patches you should install. Installing new patches immediately should keep you secure.

Here, Winkler provides a compelling example of what can happen when you don't apply patches immediately:

"The Code Red virus appeared to come out of nowhere and take over everybody overnight. What happened was that it really didn't come out overnight. The fundamental vulnerability that allowed Code Red to propagate was announced six months prior to Code Red being released.

Code Red was more of a delivery mechanism for that vulnerability. If people had patched that vulnerability when it was announced — six months prior or anytime prior in that six-month period — they wouldn't have been susceptible to Code Red.

The irony is that when the Nimda virus came out, Nimda wasn't as big, but Nimda compromised the same



This is the path a hacker might take to gain administrative privileges on your network in order to use a password sniffer to gain additional access.

underlying vulnerability as Code Red. By that point, the vulnerability was known for almost nine months and widely reported because of Code Red. Attacks that appear to come out of nowhere are, in many cases, caused by vulnerabilities that are almost a year old."

If You Think You Have Found a New Vulnerability ...

Contact the vendor for that software. First, go to their security and vulnerability lists and try to find a contact. If you can't do that, then reach the Computer Emergency Response Team (CERT) at **www.cert.org**. "Try to Email them and say you think you have found something new and are not able to get through to the vendor," Winkler advises.

You can also report viruses to CERT, though you should report them to the vendor of your anti-virus software first. They should have an email address or a channel through the program itself for virus reporting. It would be good to know the channel for reporting them before the situation arises.

There are also a few things not to do. "Many people put vulnerabilities up on Bugtraq, another mailing list [now archived at **www.securityfocus.com/archive/1**]. But that gets it out to all the bad guys sooner than the good guys and helps the bad guys break in," warns Mr. Winkler.

Realize, too, that once you have been infected, the damage is already done. Though your anti-virus vendor may have an update that will kill the bug after the fact, reporting mostly helps others to make ready before they are hit. **NV**

For More Information

1. Contact Ira Winkler, *info@isag.com*, for information about his books, presentations, pen tests, and appearances.
2. The book *Corporate Espionage* is available through **www.amazon.com** used, and new from various private sellers (though it's no longer in print, an updatedversion may be published soon).
3. Microsoft is at **www.microsoft.com**.
4. Unix, Linux, and VMS are open source systems with some proprietary exceptions.
5. CIS Contact **www.cisecurity.org**. Select Contact CIS in the top menu.
6. CERT Contact: **www.cert.org/contact_cert**.

About the Author

*David Geer is a freelance technology writer — **www.geercom.com** — and sometimes computer guru. Contact david@geercom.com.*

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IN THE SPOTLIGHT

An Interview with Mr. Ken Gracey of Parallax, Inc.

by Marvin Mallon

One of the leading suppliers of programmable microcontrollers is Parallax, Inc. The company is located in Rocklin, CA — a short commute from Sacramento. They offer a complete line of BASIC Stamp modules, SX chips, and an innovative assortment of robotics. Parallax has historically been close to the microcontroller architectures, which they support. Most recently, they have put this skill to use by designing the Propeller processor entirely on their own, transistor by transistor. The company remains privately owned and is doing gross yearly sales of approximately eight and a half million dollars.

Two friends, Chip Gracey and Lance Walley, founded the company in 1987. These longtime acquaintances shared a mutual interest in computers and anything dealing with electronics, especially Apple computers and eight-bit controllers. Lance left the organization about 10 years ago and went on to start other companies doing advanced technology design. Chip is the President of Parallax and Chief of R&D and engineering operations in the company.

Ken Gracey is the 37-year-old younger brother of Chip. He is a vice-president of Parallax and is responsible for manufacturing, marketing, sales, and support. In 1988, he was the first employee of Parallax. His duties included taking orders over the phone, building cables, and shipping orders. He left to complete a science degree at UC Davis and returned to Parallax in 1997 when the company had a need for business management.

In a recent interview with Ken, he responded to the following questions:

Marvin: How large is your facility in Rocklin? How many employees do you have?

Ken: Parallax operates in a 20,000 square-foot building. We have approximately 41 employees including a few in China and Hong Kong.

M: What is your principal business?
K: Parallax's main business is as a microcontroller design company, manufacturer, customer support, distributor, and educator. None of these specialties can exist without the others. Parallax's R&D team focuses on processor design and layout and development of boards and sensors to support our core products. An educational team shows instructors (high school and college) how to use our tutorials and microcontroller products in a classroom. The manufacturing capabilities in our facility include a full surface-mount and reflow assembly line, CNC (computerized numerical control) machining, kitting of educational products, and stress testing characterization. The sales, marketing, and support sections of the company manage the distribution and support of Parallax products worldwide.

M: What are your most popular products and when were they introduced?
K: BASIC Stamps, which were first released in 1993 and remain one of our most popular products to this day.
Parallax SX microcontrollers — eight-bit high-speed microcontrollers for which we've provided tools since 1997, and now chips. Propeller, our own custom silicon design consisting of eight processors and a shared memory. This chip is our most recent product and was released in 2006.

599 Menlo Drive, Suite 100
Rocklin, CA 95765
Tel: **888-512-1024**
Web: **www.parallax.com**.

M: On the personal side, what other interests or hobbies do you have?
K: Chip's primary interest is his family. He enjoys cooking for them and their friends when they entertain. Church activities are an important part of his family life. He gets a lot of pleasure out of running and other physical activities. At Parallax, his principal interest is chip design.

My primary interests are my family, snow sports and running, metalwork, and working with people. Parallax is also a personal interest of mine, particularly the educational "Stamps in Class" program and working with our different distributors and customers.

M: Finally, what else would you care to add about your organization?
K: From a corporate standpoint, our mission is to provide the electronics industry with products that are technically innovative, unique, and economical. This also means that we serve the hobbyist, educator, and commercial user all at once. It's really rewarding to obtain feedback from our customers and put it to use in our company. We strive to treat customers just like we would like to be treated and to keep Parallax a flexible, interesting, and stable place to work for our team. We are particularly proud of our employees and recognize them as friends and part of the company. Without their efforts, skills, and motivation to succeed, Parallax would not exist as it does today. **NV**

Understanding Digital Buffer, Gate, and Logic IC Circuits

by Ray Marston

PART 2: Digital Inverter and 'AND Gate' Circuits

Ray Marston describes practical digital inverter and AND gate logic ICs in this second installment.

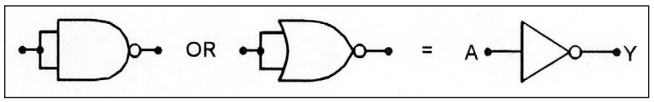


FIGURE 1. Any NAND or NOR gate can be used as an inverting buffer element.

Device	Type	Description
7404	TTL	Hex inverter
74HC04	CMOS	Hex inverter
74HCU04	CMOS	Unbuffered Hex inverter
74LS04	LS TTL	Hex inverter
74LS05	LS TTL	Hex inverter with o.c. outputs
7406	TTL	Hex inverter with o.c. outputs
74LS14	LS TTL	Hex Schmitt inverter
74HC14	CMOS	Hex Schmitt inverter
4049UB	CMOS	Unbuffered Hex inverter
74HC4049	CMOS	Hex inverter
4069UB	CMOS	Unbuffered Hex inverter
4502B	CMOS	Hex 3-state inverter
40106B	CMOS	Hex Schmitt inverter
74LS240	LS TTL	Octal 3-state Schmitt inverter

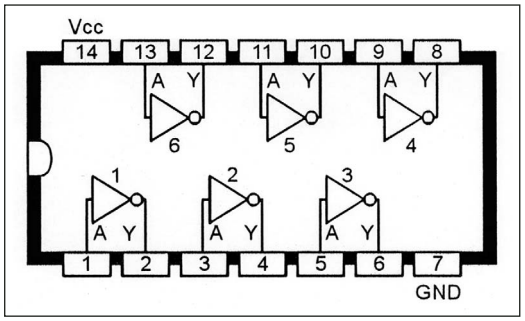
FIGURE 2. Fourteen popular inverter ICs.

Last month's opening article explained modern TTL and CMOS logic gate basics and gave practical descriptions of some of the most popular digital buffer ICs that are available. This month, we expand on this basic theme and take detailed looks at some popular digital inverter and AND gate ICs. As you read through this, note that some of the ICs mentioned may not be available via your local supplier, but should still be available from specialist dealers.

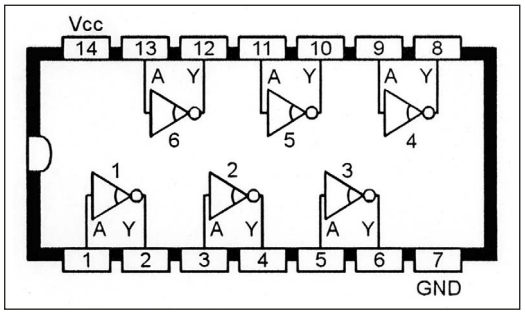
Practical Digital Inverter Circuits

The digital inverter (or NOT gate) is the most basic of all digital logic elements, and is sometimes called an inverting buffer. If you ever need only a few simple inverters, one cheap way to get them is to make them from spare TTL or CMOS NAND or NOR elements, connected in the basic way shown in Figure 1, in which the input terminals of a two input NAND or NOR gate are shorted together to accept a single input and give a single (but inverted) output signal.

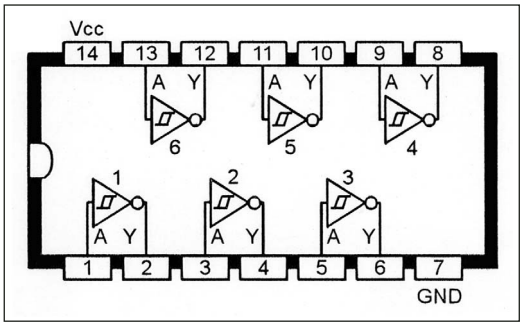
Figure 2 lists basic details of some popular digital inverter ICs. When using these ICs, note that all unused inverters must be disabled by tying their inputs to one of the IC's low voltage supply lines. In CMOS devices, the unused inputs can be tied directly to either supply line, but in TTL devices, it is best (for lowest quiescent current consumption) to tie all unused inputs directly to the 0V rail. If the unused inverter is a three-state type, it should (if it has independent controls) be set into its normal mode via its



< FIGURE 3. Functional diagram of the 7404, 74LS04, 74HC04, 74HCU04, or 4069UB Hex inverter ICs.



< FIGURE 4. Functional diagram of the 74LS05 or 7406 Hex inverters with open collector outputs.



> FIGURE 5. Functional diagram of the 74LS14, 74HC14, or 40106B Hex Schmitt inverter ICs.

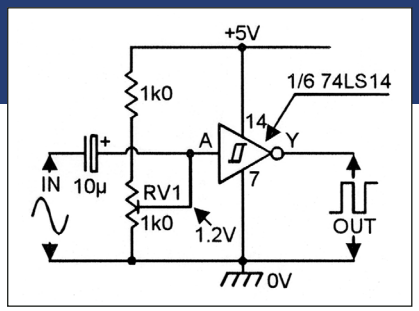


FIGURE 6. A TTL Schmitt inverter sine-to-square converter.

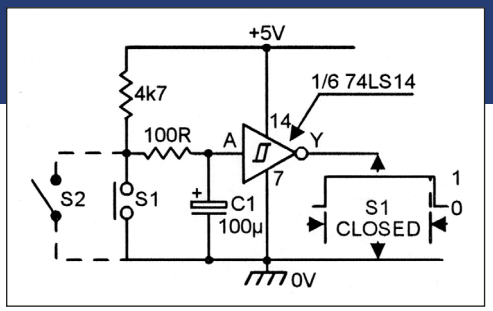


FIGURE 7. TTL switch debouncer, with logic 1 closed output.

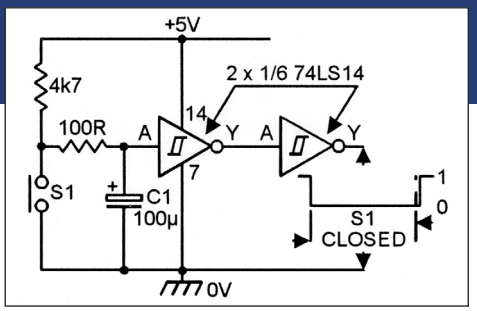


FIGURE 8. TTL switch debouncer, with logic 0 closed output.

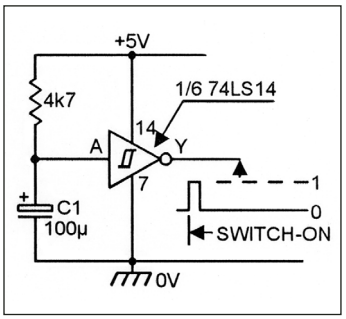


FIGURE 9. TTL supply switch-on pulse generator.

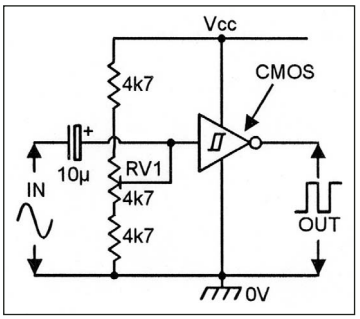


FIGURE 10. CMOS Schmitt inverter sine/square converter.

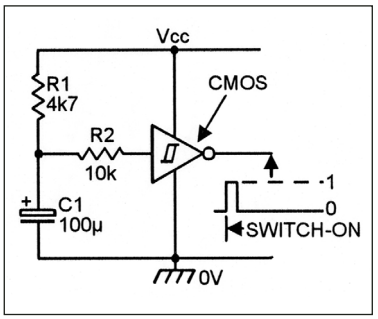


FIGURE 11. CMOS supply switch-on pulse generator.

control input, to minimize current drain.

Dealing now with the individual inverter ICs listed in Figure 2, Figure 3 shows the functional diagram that is common to the popular 7404, 74LS04, 74HC04, 74HCU04, and 4069UB Hex inverter ICs. Of these, the 7404 is an ancient standard TTL IC; the 74LS04 is a modern LS TTL type in which each inverter has a fan-out of 10, the 74HC04 is a fast CMOS type, and the 74HCU04 and 4069UB are unbuffered CMOS types that are suitable for use in linear applications.

Figure 4 shows the functional diagram that is common to the 74LS05 and 7406 Hex inverters with open collector (OC) outputs. The 74LS05's OC outputs can handle maximum outputs of only 5.5 volts, but those of the 7406 can handle up to a maximum of 30 volts.

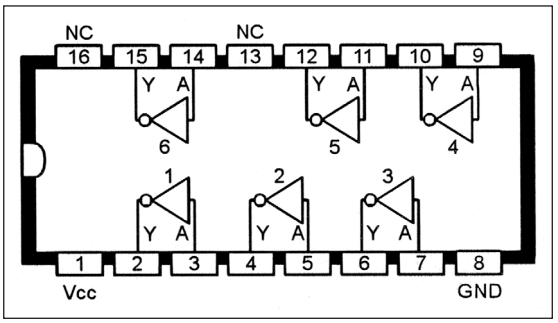
Figure 5 shows the functional diagram that is common to three of the most useful of all Hex inverter ICs — the 74LS14 TTL and the 74HC14 and 40106B CMOS Schmitt types. In the 74LS14, the output of each Schmitt inverter is in the logic 1 state until the input rises to an upper threshold value of 1.6V, at which point the output switches to logic 0 and locks there until the input is reduced to a lower threshold value of 0.8V. At this point, the output switches and locks into the logic 1 state again, and so on. Thus, a 74LS14 Schmitt inverter can be made to function as a sine-to-square converter by connecting it as shown in Figure 6, where RV1 is used to set the circuit to its maximum sensitivity point, at which a quiescent voltage of 1.2V is set on the inverter's input.

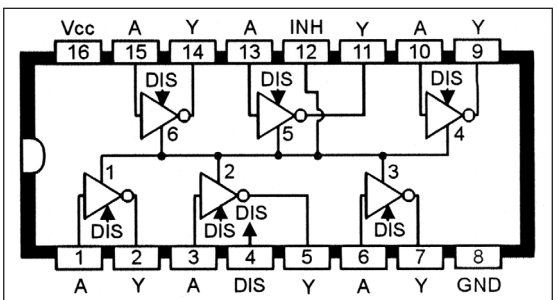
Figures 7 through 9 show more simple applications of the 74LS14 IC. Figure 7 is a practical version of a mechanical-switch contact-bounce debouncer; it can be activated by a push-button (S1) or toggle (S2) switch, and has an output that goes to logic 1 when the switch is closed. Figure 8 is a modified version of the above circuit, with an added inverter stage, and gives a logic 0 output when S1 is closed. Figure 9 is yet another variation of the basic circuit, and generates a brief logic 1 switch-on output pulse when the circuit's supply is first connected.

Regarding the 74HC14 and 40106B CMOS Schmitt inverters, these have typical upper and lower threshold voltage values equal to 60% and 40% of the supply voltage, respectively. A CMOS Schmitt inverter can thus be made to function as a sine-to-square converter by connecting it as shown in Figure 10, where RV1 is used to set the circuit to its maximum sensitivity point.

Alternatively, either CMOS Schmitt inverter can be used as a switch-on pulse generator (which generates a brief logic 1 switch-on output pulse when the circuit's supply is first connected) by wiring it as shown in

FIGURE 12. Functional diagram of the 4049UB (unbuffered) or 74HC4049 (buffered) Hex inverter IC.





DISable	INHibit	INPUT (A)	OUT (Y)
0	0	0	1
0	0	1	0
0	1	X	0
1	X	X	HI-Z

X = Don't care

FIGURE 13. Functional diagram and truth table of the 4502B Hex three-state inverter with INHIBIT control.

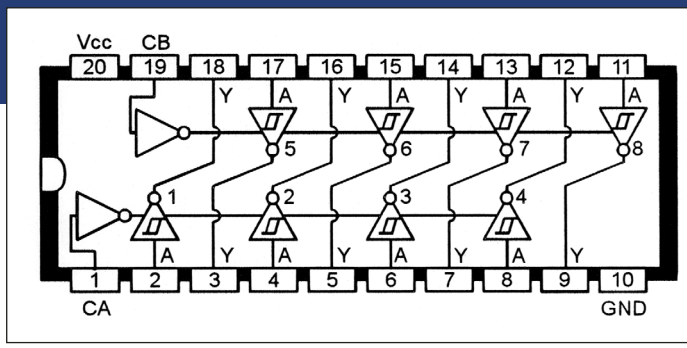


FIGURE 14. Functional diagram and truth table of the 74LS240 octal (dual quad) three-state Schmitt inverting buffer IC.

'C'	A	Y
0	0	1
0	1	0
1	0	HI-Z
1	1	HI-Z

Device	Type	Description
74LS08	LS TTL	Quad 2-input AND gate
74HC08	CMOS	Quad 2-input AND gate
4081B	CMOS	Quad 2-input AND gate
74LS11	LS TTL	Triple 3-input AND gate
4073B	CMOS	Triple 3-input AND gate
74LS21	LS TTL	Dual 4-input AND gate
4082B	CMOS	Dual 4-input AND gate

FIGURE 15. Seven popular AND gate ICs.

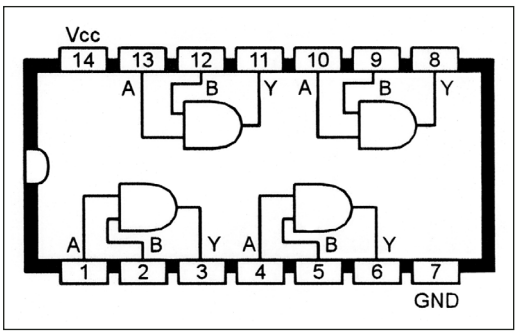


FIGURE 16. Functional diagram of the 74LS08 or 74HC08 quad two-input AND gate ICs.

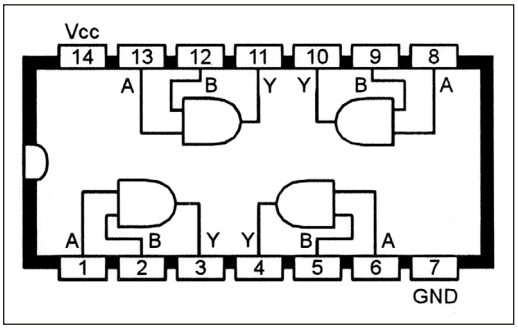


FIGURE 17. Functional diagram of the 4081B quad two-input AND gate IC.

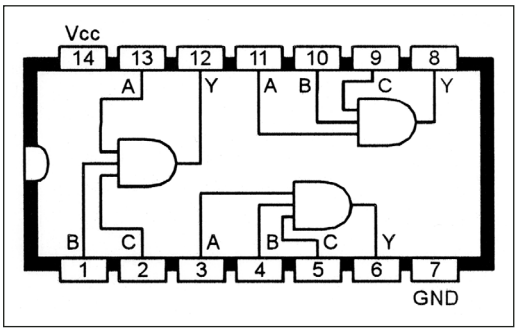


FIGURE 18. Functional diagram of the 74LS11 triple three-input AND gate IC.

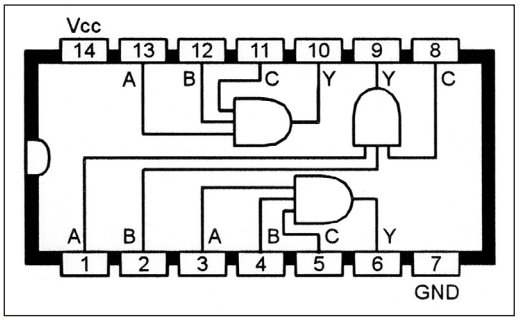


FIGURE 19. Functional diagram of the 4073B triple three-input AND gate IC.

Figure 11. Note in this circuit that resistor R2 is used to give the CMOS IC element a reasonable degree of protection against damage from excessive C1 discharge current if a short circuit suddenly appears acoss the circuit's two supply lines.

Figure 12 shows the functional diagram that is common to the 4049UB and 74HC4049 Hex CMOS inverter ICs. The 4049UB is an unbuffered type, suitable for use in linear applications, and the 74HC4049 is a fast, fully buffered general-purpose device.

Figure 13 shows the functional diagram and truth table of the 4502B. This is a special-purpose, three-state Hex inverter in which the outputs of all six inverters can be set to the logic 0 state by driving the INHIBIT (pin 12) terminal high, or can be set to the high-impedance state by driving the DISABLE (pin 4) terminal high. The IC can be used as a conventional Hex inverter by grounding the INHIBIT and DISABLE pins, or as a normal three-state inverter by grounding the INHIBIT pin and applying the three-state control to the DISABLE terminal.

Finally, Figure 14 shows the functional diagram and truth table of the 74LS240 octal three-state Schmitt inverting buffer IC, in which each buffer has a fan-out of 30. This IC is actually a dual quad device, in which inverters 1-4 are controlled via the CA terminal, and inverters 5-8 are controlled via the CB terminal. Each of these quads can be used as a set of normal Schmitt inverters by grounding the control terminal, or as a ganged set of three-state Schmitt inverters by using its control terminals as shown in the truth table.

Practical AND-Gate IC Circuits

The output of an AND gate goes high (to logic 1) when all of its inputs (A, B, and C, etc.) are high. Figure 15 lists basic details of several popular AND-gate ICs; of these, the 74LS08, 74HC08, and 4081B (see Figures 16 and 17) are quad two input types; the 74LS11 and 4073B (see Figures 18 and 19) are triple three-input types, and the 74LS21 and 4082B (see Figures 20 and 21) are dual four input types.

When using AND-gate ICs, each unwanted gate must be disabled by shorting all of its inputs together and tying them to one of the IC's supply lines. In CMOS ICs, the shorted inputs can be wired directly to either supply line, but in TTL ICs the inputs must (to give minimum quiescent current consumption with good stability) be tied to the positive supply rail via a single 1K resistor, as shown in Figure 22. A single resistor can be used as a tie point for large numbers of unwanted inputs.

Sometimes, when using three or four input AND gate ICs, you may not want to use all of a gate's input terminals. In this case, the unwanted inputs can be disabled by either tying them high (directly in CMOS gates, or via a 1K resistor in TTL types) or by simply shorting them directly to a used input. Figure 23 shows examples of three input and

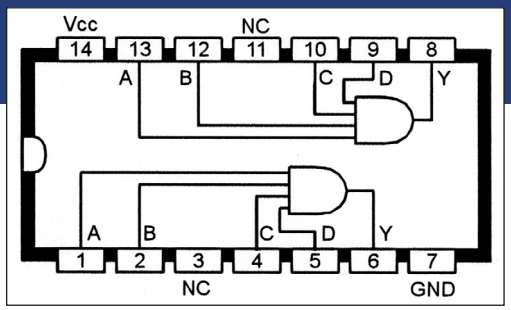


FIGURE 20. Functional diagram of the 74LS21 dual four-input AND gate IC.

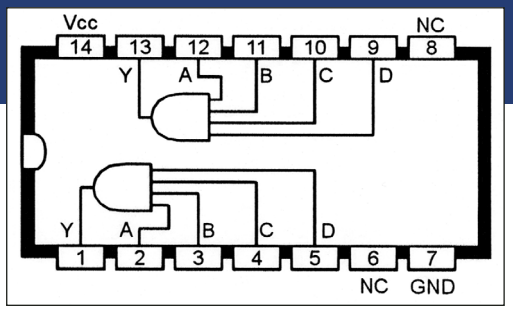


FIGURE 21. Functional diagram of the 4082B dual four-input AND gate IC.

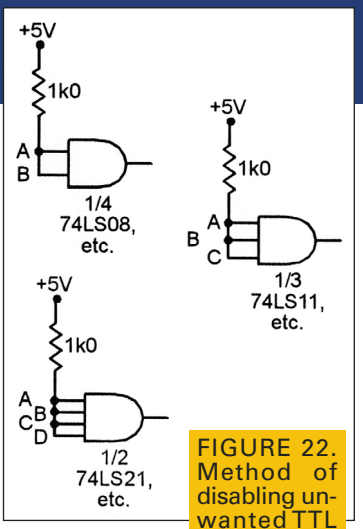


FIGURE 22. Method of disabling unwanted TTL AND gates.

four input TTL AND gates wired for use as two input types. Note that the fan-in of a TTL AND gate is an almost constant 1, irrespective of the number of inputs used. Thus, CMOS or TTL AND gates can be converted into non-inverting buffers by simply shorting all of their inputs together. Figure 24 shows examples of TTL AND gates used as simple buffers.

A useful feature of AND gate ICs is that their gates can be directly cascaded, with the output of one gate feeding directly into one input of another gate, to make compound AND gates with any desired number of inputs. Figure 25, for example, shows how two input AND gates can be cascaded to make three, four, or five input AND gates, and Figure 26 shows three three input or two four input gates cascaded to make a single seven input AND gate. **NV**

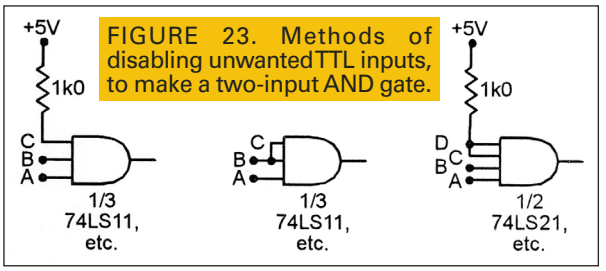


FIGURE 23. Methods of disabling unwanted TTL inputs, to make a two-input AND gate.

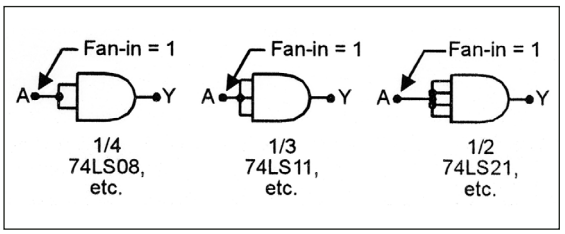


FIGURE 24. Methods of using TTL AND gates as simple buffers.

FIGURE 25. Ways of using two input AND gates to make (a) three input, (b) four input, or (c) five input AND gates.

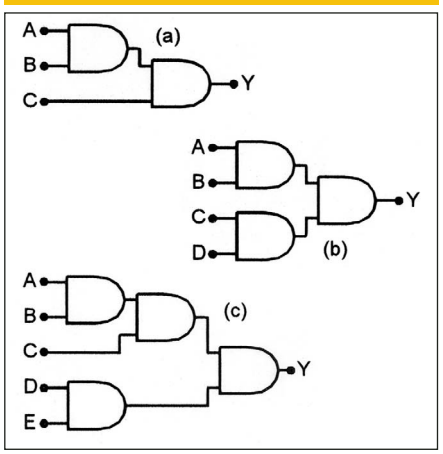
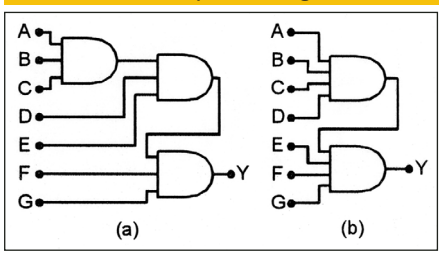


FIGURE 26. Ways of using (a) three input or (b) four input AND gates to make a seven input AND gate.



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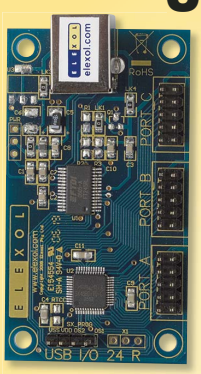

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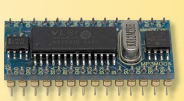

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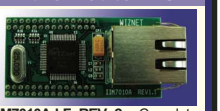

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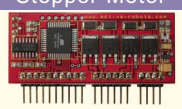

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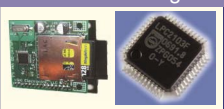

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SONIC REALISM

PART 1

by Gerard Fonte

The holy grail of high fidelity sound reproduction is to recreate the listening experience exactly. The listener shouldn't be able to tell the reproduction from the original. Yet even with expensive electronics and nearly distortion-less components there is never a difficulty with knowing what is a recording and what is live. Why? Why can't sound reproduction sound real?

It turns out that one major component of sound is not reproduced with any fidelity at all. This component is phase and it is something that is generally ignored and often improperly understood. In order to fathom phase, we will have to examine how the human hearing system operates. This is the first of two parts. The second part will provide the designs for speaker systems and techniques for recording.

Sound as a Science

Unfortunately, when it comes to sound reproduction there are many strongly held opinions. To that end, it is probably worthwhile to indicate that my position is that of scientist/engineer. I firmly believe in observation and measurement. I have difficulty accepting data as valid when blind or double-blind tests fail to support it. However, it is not unreasonable to me to consider that the ear can be sensitive to things that are not or cannot be easily measured. Phase is just such a thing.

There are three components to any sound: frequency, amplitude, and phase. These three factors completely define any and all sounds. Amplitude and frequency are easily measured. But phase is rarely considered in any sound reproduction system. There are frequency response specifications for receivers, amplifiers, speakers, and every stereo component. Amplitude specifications are also presented on the data sheet. This is seen in output power, power-handling, gain, and input values. But, where is phase detailed?

At most, there is a note mentioning the proper phasing of speakers. However, this is just to make sure that the speaker cones move in the same direction when the same signal is applied. It really has very little to do with the concept of phase as a defining characteristic of sound.

There are actually two different aspects of phase that are important. One in monaural phase (one ear) and the other is binaural phase (two ears). (References to the "ears" really means the whole hearing process.) Monaural phase sounds are typically delayed sounds that are applied to one or both ears simultaneously (more or less). A short echo (or "reverb") is a monaural phase example. You can hear an echo with either one or two ears without a problem. In this case, there are two identical sounds that are combined but offset in time. This is the type of phase we will be concerned about the most.

Binaural phase refers to the time delay due to the difference in the path length from one ear to the other. A sound from the left strikes the left ear earlier than the right ear. This type of phase is usually associated with sound localization. There is only one sound but the ears hear it at slightly different times. Obviously, both ears must participate in binaural phase perception.

Basic Sound Perception

Many people think that sound perception is a very straightforward procedure. (Note: "perception" is a personal mental act.) They view the ears as microphones and the brain as a simple receiver. Nothing could be further from the truth. Hearing is an

There are three components to any sound: frequency, amplitude, and phase. These three factors completely define any and all sounds.

extremely complicated mechanical, biological, and neurological process. This is seen when parts of this system are damaged. (A person may have perfect hearing but not be able to understand speech, for example.)

The best estimate is that hearing is a constructive process. That is, the brain takes data and applies rules and functions to that data to build a representation of the sonic world. These rules and functions are unbelievably subtle and complex. Mother Nature has spent millions of years developing the process of hearing. Unfortunately, she didn't leave any documentation behind. (One of the more unusual aspects of hearing is "objective tinnitus." Tinnitus is a ringing or noise heard that has no exterior source. It's fairly common. Objective tinnitus is a ringing or noise that can actually be heard coming from the patient's ear by a second person.)

Sound localization is usually attributed to two factors as they apply to both ears: phase and loudness. Localization is poor in humans and is usually limited to a "precision" of 10 degrees of angle or more. (Note, loudness and pitch are the perceptions associated with amplitude and frequency, respectively.) Higher frequency sounds are attenuated by the head so there is an amplitude reduction heard by the ear that is in the sound shadow. This effect starts around 100 Hz and improves at higher frequencies.

Phase, as noted above, is related to the time difference of when the sound reaches the ear. Localization of low-frequency sounds is usually attributed to binaural phase because the shadow effect doesn't work well at low frequencies. Phase is thought to contribute little to sound localization at 10,000 Hz but it increases at lower frequencies. From about 1,000 Hz and below, most localization is associated with phase.

It is useful to compare the ear's sensitivity to differences in loudness, pitch, and binaural phase. (Note that normal hearing spans 16 Hz to about 20,000 Hz with a maximum sensitivity or threshold of hearing starting at 0 dB and reaching 140 dB, where sounds are painful.) Most people can hear a difference if the amplitude of a sine wave changes by about 0.25 dB or about 3% under ideal conditions. This is quite variable depending upon the frequency and initial amplitude of the sound. But 3% is a fairly large change. It is a similar story for frequency. In this case, most people can hear a frequency shift of about 0.2% (also variable depending on frequency and amplitude). This is better than the amplitude sensitivity but it is still not all that impressive.

Binaural phase is very different. If two clicks are presented at the same time through headphones, the sound appears localized in the middle of the head. This is not surprising to anyone who has ever used headphones. By delaying one click, the sound can be made to move from side to side. This is also not too surprising. What is surprising is that if the click is delayed "by as little as 0.000012 seconds, the sound image moves towards the ear which received the click first" (Ref 1). This is only 12 microseconds! The fact that any organic system can detect a 12 microsecond difference is nearly beyond belief.

This ultra-sensitivity to phase strongly suggests that it is an important aspect in hearing. It seems unlikely that such a system developed by chance.

However, that was binaural phase sensitivity. Is there something similar for monaural phase? Initially, the answer seems to be no because delaying an ordinary sound by about 40 ms is not perceived as an echo. Nevertheless, this initial supposition turns out not to be the case.

In 1978, for my Master's thesis at the University of Buffalo, I developed a simple procedure that converted any sound into a series of pulses (somewhat similar to a nerve cell). This was a monaural experiment using one small open-air speaker in place of headphones. The pulses were identical in amplitude and width (frequency components). Therefore, no information could be conveyed by the components of amplitude or frequency. (Information requires a change in the medium in order to be transmitted. This is defined as bandwidth. Any non-varying medium, like a DC voltage, has a bandwidth of zero and cannot carry any information.)

The only parameter that varied was the time interval between the pulses. This is defined as phase. Simply, the machine took sound and removed all of the frequency and amplitude parameters while retaining only the phase parameter. Phase precision was controlled by adjusting the minimum time allowable between the pulses. A short period between the pulses permitted a greater possible number of pulses per second (depending upon the input signal) and vice versa. The results were consistent with the binaural phase measurements.

In this case, the intelligibility of speech was measured to determine how much information could be carried by phase. This value turned out to be 100% with high pulse rates. While the elimination of amplitude and frequency components distorted the speech, the intelligibility was identical to the control. As the pulse rate was lowered, the intelligibility fell (as did the bandwidth). This allowed the comparison of intelligibility to pulse rate.

The result was that there was a 1% change in intelligibility with a 14 microsecond change in the phase (delay between pulses). It would seem to support the notion that phase is important in the hearing and speech perception processes. (Note that 14 microseconds corresponds to an acoustic path length of about 0.185". A sine wave with a period of 14 microseconds is equivalent to a signal with a frequency of over 71,000 Hz.)

Speakers and Phase

So what does all this have to do

with Hi-Fi? Quite simply, virtually all the speaker systems on the market today destroy the proper phase relationships of the sounds that they reproduce. The fundamental reason for this is because of the practical limitations of the speakers (drivers) themselves. A single driver cannot reproduce the full range of frequencies that the ear can hear. In order to do so, multiple speakers are used. This is obvious. Tweeters are hopeless at providing booming base and woofers fade away at two or three thousand Hertz. The requirement of multiple speakers is the underlying problem.

Figure 1 illustrates a typical speaker setup. It consists of a tweeter and a woofer. For convenience, the speaker enclosure is placed on a support at ear level. In this way, the direct line distance from the tweeter and the woofer to the ear are the same. This means that the sounds from both speakers reach the ear at the same time. However, a typical ceiling is an excellent reflector of sound. There is a second acoustic path from the speaker to the ear that results from a reflection from the ceiling. So a reflected signal from the woofer, which is lower to the floor, will travel farther than a reflected signal from the tweeter, which is closer to the ceiling.

This changes the phase relationships and the wave-shape (see Photos 1 and 2). The more drivers that there are in the speaker system, the greater this phase distortion will be. There is also the reflection from the floor, as well as from other large objects in the room. These additional reflections will not be considered in order to keep things as simple as possible.

It is important to remember that ordinary sounds are not sine waves but complicated combinations of sine waves that span many octaves. Speech is a good example. In order for speech to be intelligible, the frequencies of about 300 Hz to 3,000 Hz must be reproduced. However, few people think that a telephone produces high fidelity reproduction of someone talking. Natural speech contains sound components from about 100 Hz to over 10,000 Hz.

Let's examine what happens to speech when it is reproduced by the speaker system in Figure 1. The speaker's cross-over directs the high frequency components to the tweeter and the low frequency components to the woofer (if no cross-over is used, the natural response curves of the drivers perform the same function but less effectively). For the direct line path, the ear hears all of the components at the same time and their phase relationships are maintained. However, with a typical speaker system shown in Figure 1, the high frequency sounds reflected off the ceiling are heard first with the lower sounds bringing up the rear. The phase relationships of the reflected sounds are destroyed. In effect, the ear hears a different signal coming from the direction of the ceiling. Again refer to Photos 1 and 2.

The two photos show what happens when a signal consisting of 1,000 Hz and 3,000 Hz components is reproduced. The 1,000 Hz signal is routed to the woofer and the 3,000 Hz signal goes to the tweeter. The original signal is shown in Photo 1 and this is what is heard if both speakers are equidistant from the ear.

If there is a path length difference between the woofer and tweeter of only two inches (or multiple of two inches), the ear receives significantly distorted signal that is shown in Photo 2. Obviously, with signals consisting of many frequency components and many signal paths, the reflected wave shapes can be vastly different from the original. These distortions are the direct result of the loss of phase information.

Acoustic Peculiarities

One of the tell-tale indicators that this different signal is important is seen in the common problem of stereo setup. If I stand next to one speaker I will often have difficulty in determining if the other speaker is operating. But, this shouldn't happen. If I'm talking to one person next to me and someone else 10 feet away starts talking, I certainly know that. I may not be able to understand that person because of the nearby person's voice, but I surely hear that the far person is speaking. The same should be true of the far stereo speaker. The sounds coming out of that speaker are different from the close one (otherwise it wouldn't be stereo).

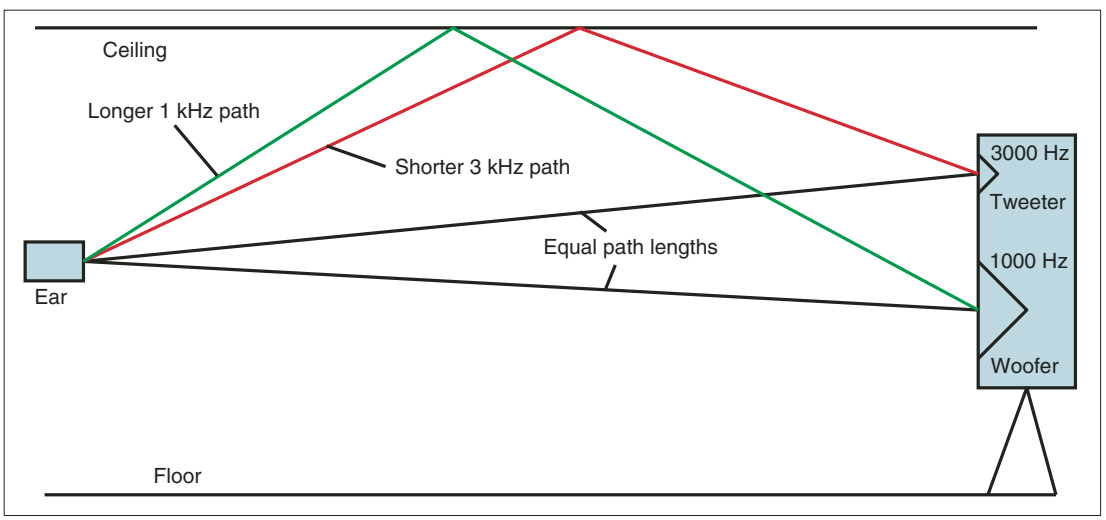

FIGURE 1. The fundamental problem with most speaker systems is that multiple drivers are required. This separates the high and low frequencies to different physical locations. The result is that reflected sounds have different acoustic path lengths for different frequencies. This is phase distortion.

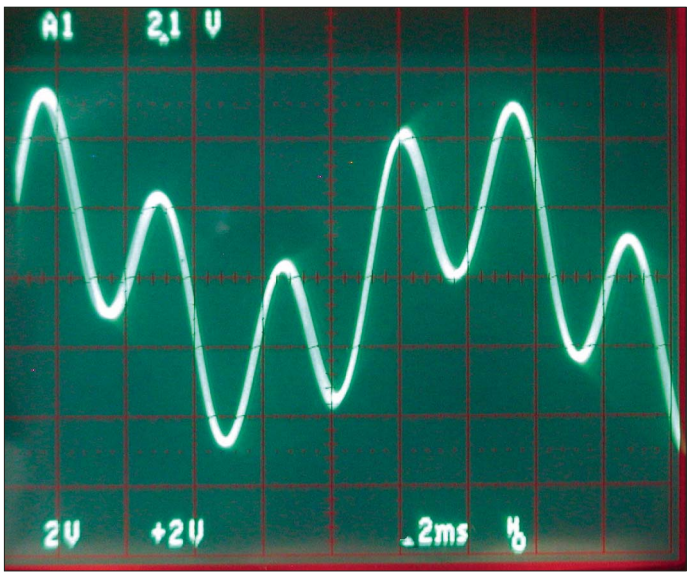

PHOTO 1. A signal that consists of 3,000 Hz and 1,000 Hz sine waves. This is the "proper" signal and is what the ear hears if the acoustic path lengths of the tweeter and woofer are the same.

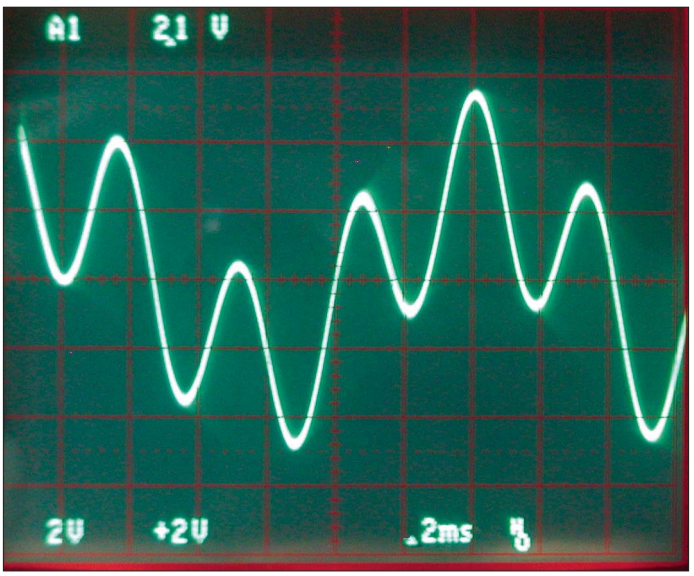

PHOTO 2. The same signal as Photo 1 except that the acoustic path length for the 3,000 sine wave has changed by about two inches (about 180 degrees) relative to the 1,000 Hz sine wave. The shape is considerably different from Photo 1.

This makes sense only if there is a difference between a person's voice and a reproduction of a person's voice. The only significant difference is phase. The reflections of a person's voice do not suffer from phase distortion because all the signals come from a single point. There is no break-up of the voice signal into multiple frequency channels where each channel has a different physical location.

Then there is the strange effect heard when recording a conversation in an ordinary room. If the microphone is some distance from the person speaking, it often sounds as if the recording was made in a tin can or at the bottom of the well. (Police undercover recordings are a typical example.) Sometimes the speech is nearly unintelligible. However, if you were present during the recording, you didn't notice anything odd. Why?

There are two factors at work in this second example: reflection and auto-correlation. Sound reflects well from hard surfaces. Often, there is only about one dB or so of loss (or about 90% reflection). If a microphone is held about a foot from the mouth of someone speaking, the sound level is about 65 to 70 dB for normal speech. This level follows an inverse-square relationship as the distance increases. At two feet, the level is 50% or 6 dB down, and so forth. If there is a wall four feet away from the person speaking, then the echo returning from the wall is about 24 dB down (excluding wall losses) and delayed by about 8 mS. This is a very substantial amplitude difference.

However, if the microphone is four feet from the person and there is a wall four feet beyond the microphone, the echo will be only 6 dB down (and delayed by 8 ms). This is not a very large volume difference when considering that speech varies considerably in amplitude. Thus, the reflection is perceived as being virtually as loud as the person speaking. This can be compared to one person speaking from four feet and another speaking from 12 feet. It is clear that in such a situation, both people will be heard at a reasonably similar loudness. So, the tape recording presents the speaker and the echo at nearly the same volume. That explains the tin can effect as a reverb. This reasoning seems acceptable but it doesn't explain why the reverb isn't heard by people in the room when the recording was made.

Auto-Correlation

The reason reverb isn't heard by people in the room is because the ear apparently possesses an auto-correlation function (or its equivalent). This is clearly demonstrated by the fact that humans do not perceive short-term echos (delays of less than about 40 ms). But we certainly do perceive echos with delays longer than that. This seems to conflict with the demonstrated sensitivity of the ear to delays of about 14 µs. This is a difference by a factor of nearly 3,000. It implies that something is happening to sounds that are delayed from 14 µs to about 40 ms.

Auto-correlation is a technique that allows the removal of echos. (This is an important issue with the telephone companies who have done a lot of work on the subject.) The concept is fairly simple. If a delayed signal is identical to an earlier signal, then the second signal must be an echo and can be removed. The method of determining "identical" is a statistical process called auto-correlation. It compares, or correlates, different parts of the signal, looking for similarities. If the different signal parts are similar, then there is a high auto-correlation.

This explains why the recording sounds very different. If you were in the room, your hearing system can apply many tools to clarify the speech. Primarily there is binaural auto-correlation that can be used. Then there is sound-shadowing (from your head) to localize the person speaking. Monaural auto-correlation can be employed as well, since your brain "knows" that any identical sound coming from a different direction must be an echo. You have a visual reference as well, which certainly has the potential to assist in localization. Lastly, the sonic characteristics of the room itself can provide useable cues.

Auto-correlation cleans up the voices and makes them much more intelligible. It also explains why auto-correlation stops around 40 ms and echos are then heard. This may be because the shortest speech sound is also about 40 ms long. If an auto-correlation system was longer than that, it is possible that short speech sounds would be degraded because speech contains many repeated sounds. Obviously, the speech and hearing mechanisms must be compatible in order for them to function properly.

This finally provides a clear explanation of why phase is so important. The auto-correlation function fails with reflected multiple-driver, speaker systems because wave shape is significantly changed. Photos 1 and 2 show a distinct difference in wave shape. The ear perceives this as a different sound coming from a different direction. This is why ordinary speaker systems do not and cannot sound like the real thing.

Conclusion

This has been a very cursory examination of the human hearing system with a focus on phase. We saw that hearing is very complicated and employs subtle and sophisticated functions associated with phase. We also saw that the ear's sensitivity to phase is extremely high. Finally, it was shown that common speaker systems with more than one driver ruin the phase relationships. This is because sound reflections from the ceiling (or floor, etc.) do not maintain the same phase relationships as the direct line sound.

In the next part, two different speaker systems will be detailed that the provide proper phase relationships regardless of path length differences. A high-fidelity system will also be described that produces a qualitative difference in sonic reality. Ordinary stereo recordings and/or stereo FM broadcasts will be used as the source material. Recording considerations will also be discussed. **NV**

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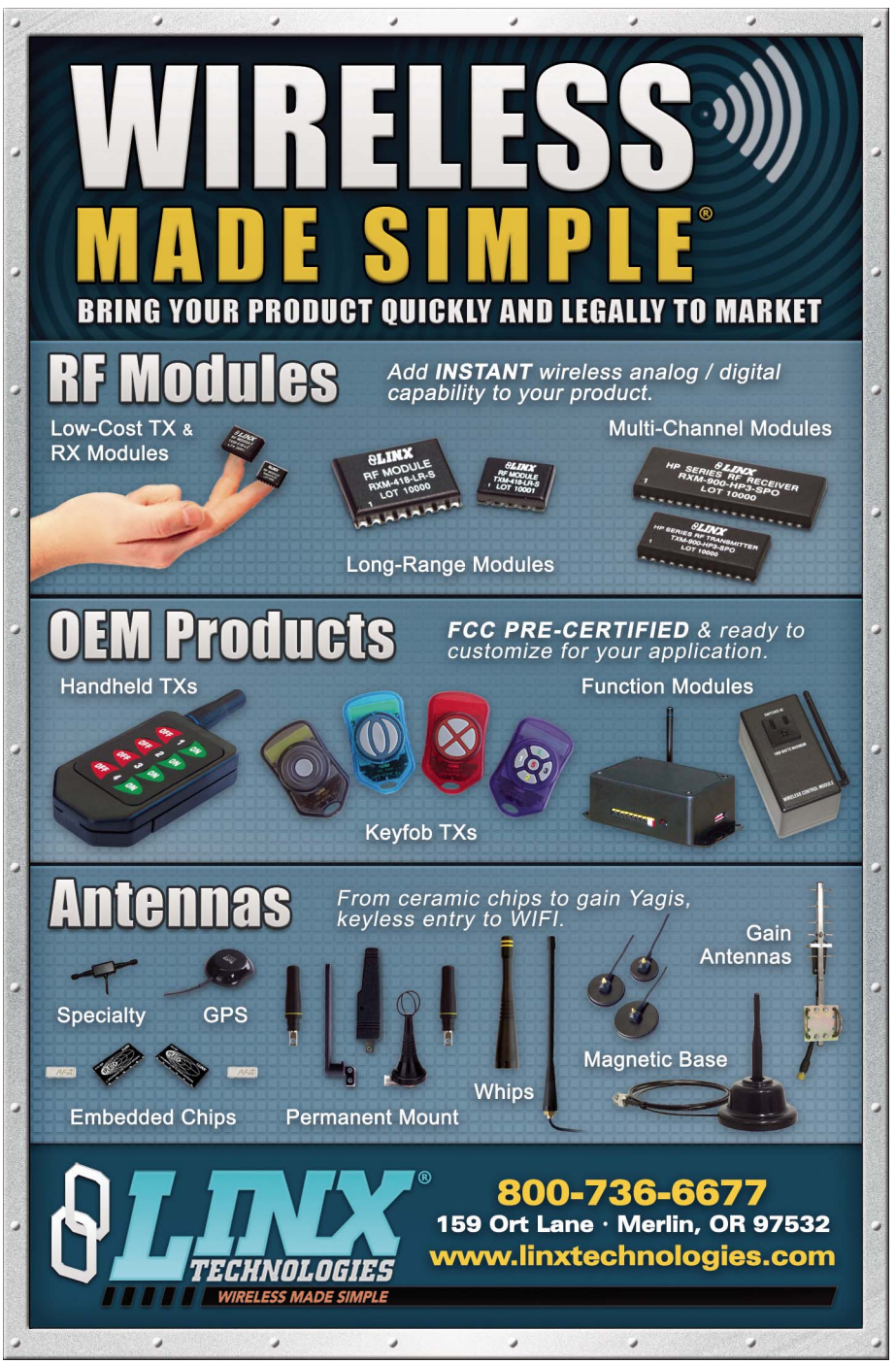
REF 1: *Normal Aspects of Speech, Hearing and Language*; Minifie, Hixon, Williams, 1973, Prentice-Hall



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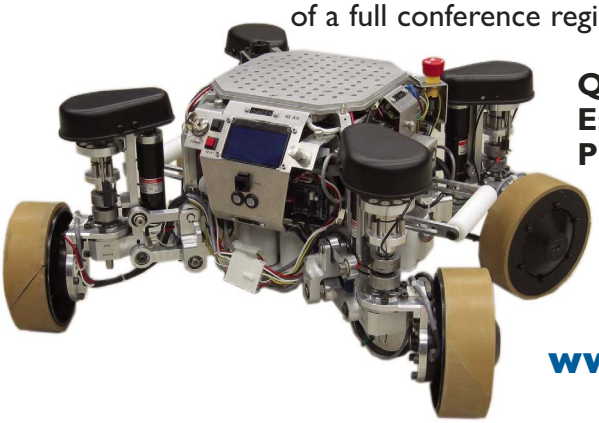

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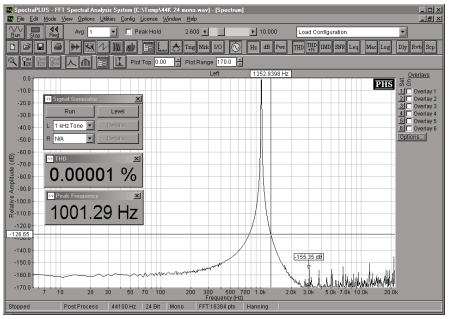

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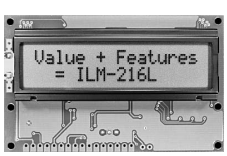

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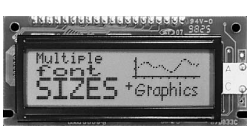

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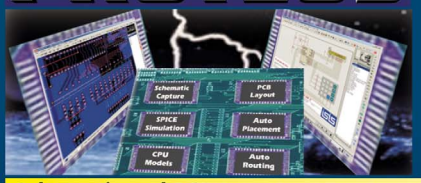

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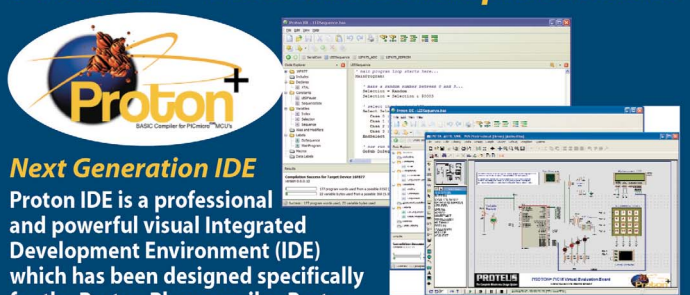

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■ BY PETER BEST

CONFIGURATION WIZARDRY

IF YOU'RE STANDING UP, MAYBE YOU WANT TO TAKE A SEAT. Last time, we started our indepth look at what makes the C8051F120 a premier 8051 drop-in solution. That Digital Crossbar stuff we looked at seemed mighty complicated. Well, after taking some time to read the C8051F120 datasheet, I fell upon a thing called Configuration Wizard 2. I'm sorry to have to break this to you, but the Configuration Wizard 2 application takes every bit of complication out of configuring any of the C8051F120's general-purpose I/Os, peripherals, and the Digital Crossbar. And, Configuration Wizard 2 is free as a download from the Silicon Laboratories website.

USING THE SILICON LABORATORIES CONFIGURATION WIZARD 2

I fired up the Configuration Wizard 2 application and selected the C8051F120 as the target device. Up popped an "untitled C8051F120" configuration window that contained the following text:

```
//-----------------------------------------------------------
//-----------------------------------
//  Generated Initialization File  //
//-----------------------------------

#include "C8051F120.h"

// Initialization function for device,
// Call Init_Device() from your main program
void Init_Device(void)
{
}

// Empty configuration

// Open the "Peripherals" menu and
// choose a peripheral to configure.
//-----------------------------------------------------------
```

I took the liberty to save the raw Configuration Wizard 2 file as ".nuts_and_volts.cwg" (imagine that), which is available on the *Nuts & Volts* website (**www.nutsvolts.com**). Keep in mind that I haven't written a line of anybody's source code at this point. The Configuration Wizard 2 application automatically stuffed in the `#include "C8051F120.h"` statement and built the *Init_Device* function skeleton you see in the previous code snippet.

I don't know about you, but I've had close encounters of the third kind with lots of configuration and program wizards. My best advice to you is to read their output messages and comments carefully and heed the wisdom contained within the messages as ignoring a wizard's sage advice can lead to trouble. With that, I followed the light offered by the last comment in the generated initialization file and opened the Configuration Wizard 2 "Peripherals" menu. What I saw is what you see captured in Figure 1.

CONFIGURING C8051F120 GENERAL-PURPOSE I/O PINS

I decided to go down the Configuration Wizard 2 Port I/O path as we already examined how to logically set up bit 6 of Port 1 (P1.6) for output in the previous installment of Design Cycle. Note that in Figure 2, I configured P1.6 for push-pull digital operation and enabled the Digital Crossbar. If you're having trouble finding the P1.6 configuration change, follow along the Push-Pull/Open Drain row near the bottom of Figure 2. Note also that the code to perform the P1.6 configuration operation appears in the bottom window of Figure 2. If you look back to the previous issue of *Nuts & Volts*, you'll see the code that was generated by the Configuration Wizard 2 application here to enable the Digital Crossbar and set up general-purpose I/O pin P1.6 matches the Digital Crossbar/P1.6 configuration code we studied in the previous Design Cycle column. This is promising.

This gets better. In the *Port_IO_Init* function snippet that follows, I've culled out the C8051F120 general-purpose I/O comments and code that we are most interested in:

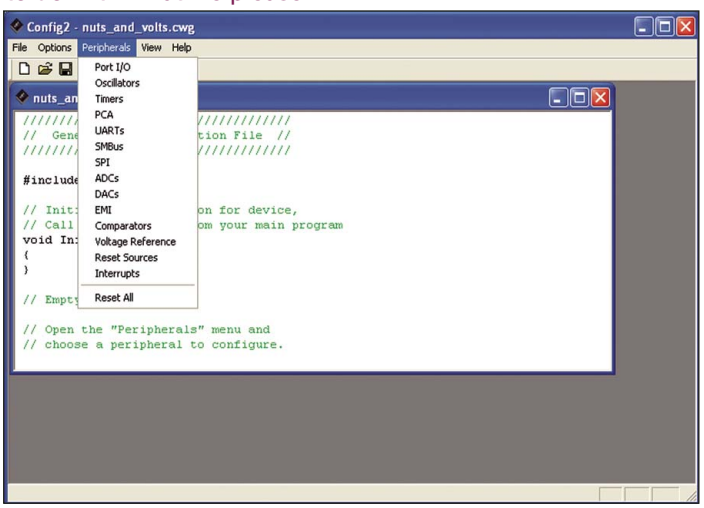
```
//-----------------------------------------------------------
void Port_IO_Init()
{
    // P1.0  -  Unassigned,  Open-Drain, Digital
    // P1.1  -  Unassigned,  Open-Drain, Digital
    // P1.2  -  Unassigned,  Open-Drain, Digital
    // P1.3  -  Unassigned,  Open-Drain, Digital
    // P1.4  -  Unassigned,  Open-Drain, Digital
    // P1.5  -  Unassigned,  Open-Drain, Digital
    // P1.6  -  Unassigned,  Push-Pull,  Digital <---
    //                                     our change
    // P1.7  -  Unassigned,  Open-Drain, Digital

    SFRPAGE   = CONFIG_PAGE;
    P1MDOUT   = 0x40;
    XBR2      = 0x40;
}
//-----------------------------------------------------------
```

It's rather obvious in the *Port_IO_Init* function code that not only did the Configuration Wizard 2 application create the *Port_IO_Init* function, it populated the *Port_IO_Init* function structure with the code that is necessary to activate the Digital Crossbar and configure general-purpose I/O pin P1.6 as a push-pull digital output. The generation of C8051F120 source code doesn't stop here. Not only did the Configuration Wizard 2 application generate a new general-purpose I/O function, it entered a call to the newly generated *Port_IO_Init* function in the *Init_Device* function that we will eventually call from our main application. I've pulled the newly altered *Init_Device* function out from the main code body for you to see in the *Init_Device* function code snippet that follows:

```
//-----------------------------------------------------------
// Initialization function for device,
// Call Init_Device() from your main program
void Init_Device(void)
{
    Port_IO_Init();
}
//-----------------------------------------------------------
```

■ FIGURE 1. Wizards are usually good things. In this case, the Configuration Wizard 2 application has opened up the entire C8051F120 peripheral and general-purpose I/O collection to us to do with what we please.



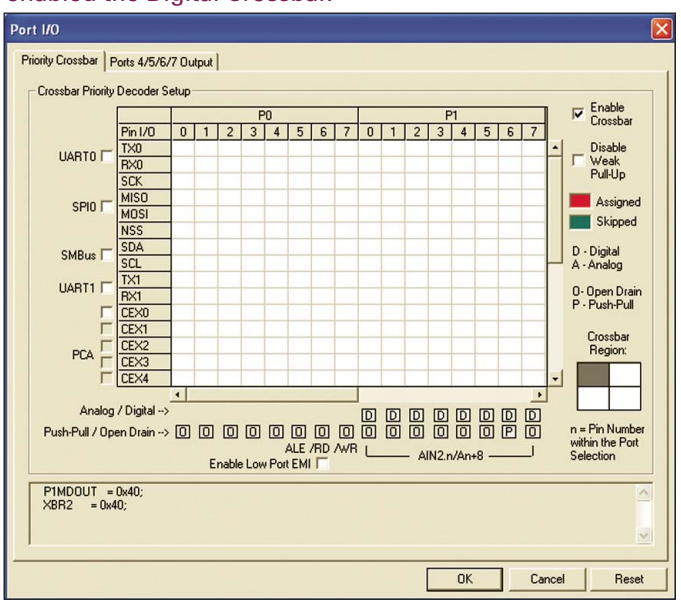
USING CONFIGURATION WIZARD 2 TO CONFIGURE THE C8051F120 OSCILLATOR

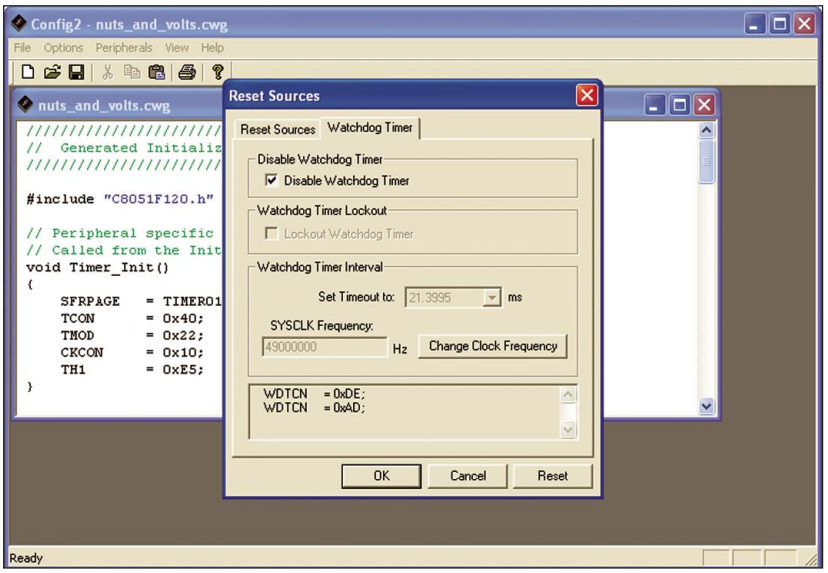
The C8051F120 has its own internal oscillator. However, the C8051F120 can also be clocked by an external crystal. It seems that no code is generated if the C8051F120 internal oscillator is configured for its most basic operational mode. We want some action. So, I configured the C8051F120 to use an external 22.1184 MHz crystal to supply the C8051F120's SYSCLK. There's not a lot of pretty interactive screen play as we kinda saw with the general-purpose I/O configuration. However, the results generated by the Configuration Wizard 2 application are indeed impressive. If you want to check the Configuration Wizard 2 application's work, you'll find that the OSCXCN value in the *Oscillator_Init* function below breaks down as follows. The upper nibble (0x6_) puts the C8051F120 into crystal oscillator mode. The lower nibble of OSCXCN (0x_7) is set up for a crystal frequency that is greater than 10 MHz and lower than 30 MHz. The most significant bit of OSCXCN is set when the crystal oscillator is stable.

```
//-----------------------------------------------------------
void Oscillator_Init()
{
    int i = 0;
    SFRPAGE   = CONFIG_PAGE;
    OSCXCN    = 0x67;
    for (i = 0; i < 3000; i++);  // Wait 1ms for
                                 // initialization
    while ((OSCXCN & 0x80) == 0);
    CLKSEL    = 0x01;
}
//-----------------------------------------------------------
```

The least significant bit of the CLKSEL register is set to

■ FIGURE 2. Look closely along the Push-Pull/Open Drain line at the bottom of this shot to see the configuration change I made to the P1.6 general-purpose I/O pin. Also, notice I enabled the Digital Crossbar.





■ FIGURE 3. We're not writing code for an F-18 targeting and navigation system. So, we can do without the failsafe services of the C8051F120's watchdog timer for now.

Configuration Wizard 2 application allows us to do this by entering the Reset Sources area of the Peripheral pull-down menu (see Figure 1). As you can see in Figure 3, a simple check box entry does the job of disabling the C8051F120's watchdog timer. Is this fly-by-wire or what?

RUN LIKE HECK

Now that we've put the dog to bed, let's configure the C8051F120's oscillator. Everything we do with the UART baud rate is based on the frequency of the C8051F120 system clock. I'll bet that you can manipulate the Configuration Wizard 2 application Oscillator Peripheral settings to generate the oscillator code that follows:

```
//-----------------------------------------------------------
void Oscillator_Init()
{
    int i = 0;
    SFRPAGE = CONFIG_PAGE;
    OSCICN = 0x83;              // set internal osc
                                //  to run at its
                                //  maximum frequency
    CCH0CN &= ~0x20;            // disable cache
                                //  prefetch
    SFRPAGE = LEGACY_PAGE;
    FLSCL = 0x10;               // set flash read
                                //  timing for <=50MHz
    SFRPAGE = CONFIG_PAGE;
    CCH0CN |= 0x20;             // enable cache prefetch
    PLL0CN |= 0x01;             // power up PLL
    PLL0DIV = 0x01;             // PLL pre-divider =1:1
    PLL0FLT = 0x21;             // PLL output clock
                                //  = 30-60 MHz
                                // PLL reference clock
                                //  = 19-30 MHz
    PLL0MUL = 0x02;             // PLL multiplier = 2X
    for (i = 0; i < 15; i++);   // Wait 5us for init
      PLL0CN |= 0x02;
    while ((PLL0CN & 0x10) == 0);
    CLKSEL = 0x02;              // output = SYSCLK
                                // SYSCLK derived from
                                //  PLL
}
//-----------------------------------------------------------
```

An analysis of the *Oscillator_Init* function reveals that we want to clock the C8051F120 using its internal oscillator. The maximum unassisted clock speed we can attain with the C8051F120's internal oscillator is 24.5 MHz (OSCICN). Ultimately, we will use the C8051F120's PLL (Phase Locked Loop) to double the maximum internal oscillator frequency (PLL0MUL), which will clock the C8051F120 at 49 MHz. We must compensate the C8051F120's internal Flash memory read/write system to allow reliable Flash reads and writes at 49 MHz (FLSCL).

configure the C8051F120 to get its SYSCLK from the external crystal oscillator. You're a savvy Design Cycle reader and I'm sure you're beginning to follow the logic behind the Configuration Wizard 2 application. The new crystal oscillator function, *Oscillator_Init*, is set to be called from the *Init_Device* function just like the general-purpose I/O function we generated earlier. Here's our updated *Init_Device* function:

```
//-----------------------------------------------------------
// Initialization function for device,
// Call Init_Device() from your main program
void Init_Device(void)
{
    Port_IO_Init();
    Oscillator_Init();
}
//-----------------------------------------------------------
```

STEP OUT OF THE TRUCK

If you're following along with your copy of Configuration Wizard 2, you'll see that Timers would be the next logical step that we would take in our journey through the Configuration Wizard 2 application. Let's pull off the road we're on, get out of the truck, and walk a different path. Instead of configuring a Timer, let's put a working UART configuration together. A UART configuration requires more than just setting up the UART registers. In addition to twiddling the UART configuration bits, we must also reconfigure the C8051F120's oscillator, prepare the C8051F120's Timer 1, and set up the UART I/O pins. Don't worry, the Configuration Wizard 2 application takes all of that into account and doesn't miss a beat in the UART initialization and setup process.

KNOCK OUT THE DOG

Before we do anything towards our UART configuration, we will disable the C8051F120's watchdog timer. The

Once the C8051F120's Flash memory system is set up for our SYSCLK speed of 49 MHz, we can activate the PLL (PLL0CN) and configure the PLL filters for 49 MHz operation (PLL0FLT). The PLL needs some time to stabilize and when the PLLCK bit (PLL0CN register bit 4) transitions from low to high, the PLL has locked into the desired frequency. At this point, the C8051F120's PLL is the SYSCLK clock source.

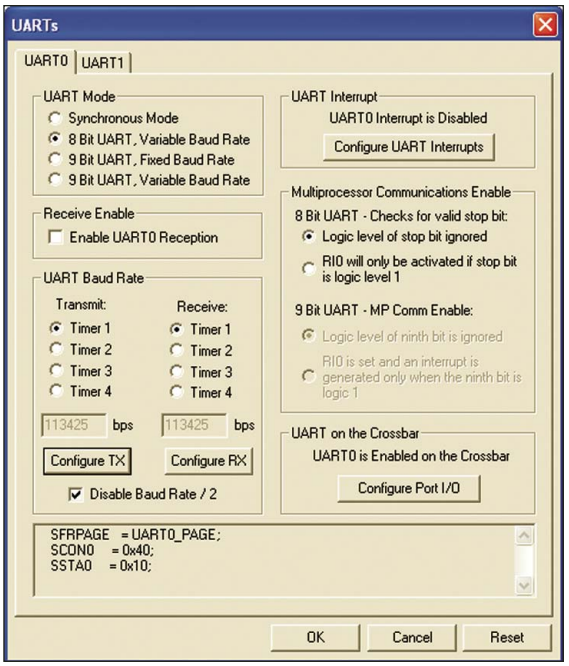
ACTIVATING UART0

Okay, the stage is set for us to get one of the C8051F120's UARTs on the air. Selecting the UART option from the Peripheral pull-down menu results in the display you see in Figure 4. In Figure 4, I've already performed all of the UART configuration steps, which explains why the UART0 is on the Digital Crossbar, Timer 1 is the baud clock source, and the baud rate is set for 115200 bps. Although I've greased the skids, we can still work through the UART0 configuration process together.

I went down the Configure Port I/O path in Figure 4 to get to the configuration screen shown in Figure 5. By selecting UART0, I attached UART0's transmit and receive pins to the C8051F120's general-purpose I/O pins P0.0 and P0.1 respectively via the Digital Crossbar. If you follow along the Push-Pull / Open Drain general-purpose I/O status line in Figure 5, you'll see that I also configured the UART0 transmit and receive pins as push-pull. How did I know to do that? I read the UART0 section of the C8051F120 datasheet and followed the rules that are laid down there. I may not be the sharpest tool in the shed, but I follow directions well.

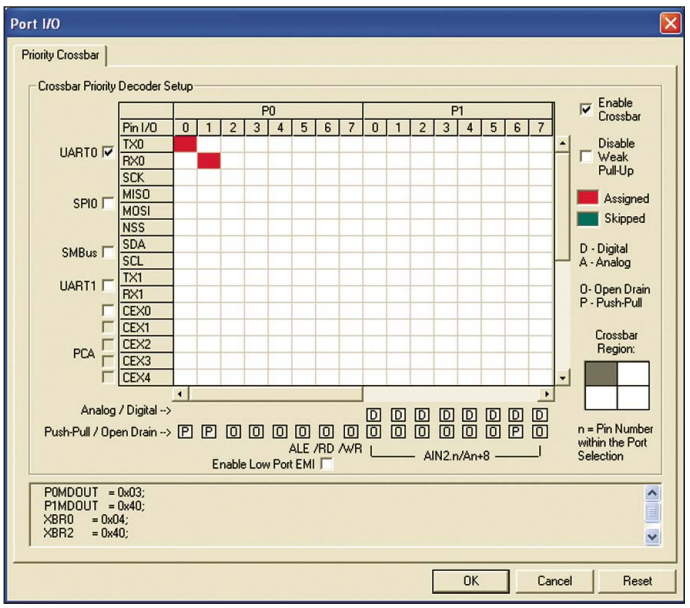
Since we want to be able to make our C8051F120 UART communicate with a standard terminal emulator running on a personal computer or another RS-232 equipped device, I selected standard eight-bit mode (see UART Mode in Figure 4), which allows us to use various standard baud rates and provides for a start bit and one stop bit in the asynchronous communications bit stream (10 bits total). No rocket science here. The baud clock for this mode of UART operation can be provided by any of the available C8051F120 timers.

■ FIGURE 4. This window reminds me of that TV show *Let's Make A Deal*. There are lots of knobs and switches behind the "doors" in this shot.



Taking the Configure TX path in Figure 4 opens the window shown in Figure 6. As you can see, I've selected the aforementioned Timer Mode (Eight-Bit Timer/Counter Auto-Reload), identified the Timer 1 clock source as SYSCLK, and enabled Timer 1. Our baud rate of choice is 115200 (I hope that's okay with you) and I set that up by clicking the Change Baud Rate button you see in Figure 6 and entering my desired baud rate for UART0. The Configuration Wizard 2 application determined the reload value for Timer 1 that will supply a baud clock for 115200 bps. The reload value (0xE5) is loaded into the high byte (TH1) register of Timer 1 on every overflow of Timer 1. A Timer 1 overflow occurs when Timer 1 rolls over from all ones to zero. The low byte register (TL1) is always loaded with 0x00.

Lots of stuff happened while configuring UART0. In the course of putting together the bits and pieces needed to spit bits from UART0's transmit pin, Timer 1 was configured and enabled. Here's the UART0-related Timer 1 code that the Configuration Wizard 2 application generated for us:



■ FIGURE 5. In my opinion, this is the coolest window that the Configuration Wizard 2 application offers. At a glance, we can see all of the C8051F120's general-purpose I/O and peripheral configuration settings.

SOURCES

■ *Keil — An ARM Company* (**www.keil.com**) — Keil C51 C Compiler.

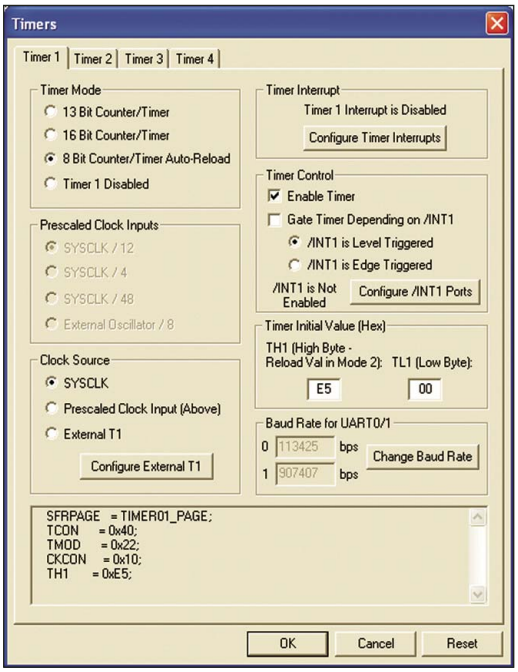
■ *Silicon Laboratories* (**www.silabs.com**) — C8051F120; C8051F120 Development Kit; USB Debug Adapter.

```
//-----------------------------------------------------
void Timer_Init()
{
    SFRPAGE = TIMER01_PAGE;      // enable access to the
                                 //  Timer1 register set
    TCON = 0x40;                 // enable Timer1
    TMOD = 0x22;                 // Timer1 to Mode 2
                                 // 8-bit Counter/Timer
                                 //  with Auto-Reload
    CKCON = 0x10;                // Timer1 uses system
                                 //  clock
    TH1 = 0xE5;                  // Timer1 reload value
                                 //  for 115200 baud
}
//-----------------------------------------------------
```

If you're wondering where the "Mode 2" wording came from in the *Timer_Init* function, it is the name that the C8051F120 datasheet uses to describe the eight-bit Counter/Timer with Auto-Reload mode of operation. I'm not going to insult your intelligence as everything you need to know about the *Timer_Init* function can be found in the function's comments. I already checked the Configuration Wizard 2 application's work and the bits generated by the Configuration Wizard 2 application in the *Timer_Init* function match the C8051F120 datasheet declarations.

Bringing up UART0 also required an addition to our *Port_IO_Init* function code. Recall that the UART0 transmit and receive pins needed to be configured for push-pull operation. Here's the new code that the Configuration Wizard 2 application generated and pushed into the existing *Port_IO_Init* function:

■ FIGURE 6. To my amazement, the Configuration Wizard 2 application correctly calculated the reload value. The ultimate test will be to see if we can issue a printf statement and get something we can read in the Tera Term Pro window.




```
//-----------------------------------------------------
void Port_IO_Init()
{
    SFRPAGE = CONFIG_PAGE;       // enable access to
                                 //  port config regs
    P0MDOUT = 0x03;              // push-pull on P0.0
                                 //  and P0.1
    P1MDOUT = 0x40;              // push-pull on P1.6
    XBR0 = 0x04;                 // enable UART0
    XBR2 = 0x40;                 // Digital Crossbar
                                 //  enabled
}
//-----------------------------------------------------
```

Of course, the UART0 bits were twiddled in the fray:

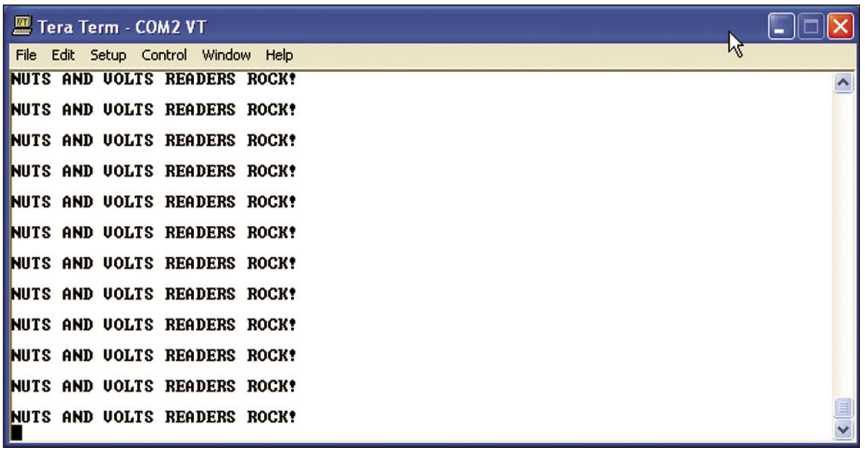
```
//-----------------------------------------------------
void UART0_Init (void)
{
   SFRPAGE = UART0_PAGE;         // enable access to
                                 //  UART0 registers
   SCON0 = 0x40;                 // UART0 serial port
                                 //  mode = 8-bit Timer/
                                 //  Counter Auto-Reload
   SSTA0 = 0x10;                 // disable baud rate
                                 //  divide by 2
   TI0 = 1;                      // Indicate TX0 ready
}
//-----------------------------------------------------
```

The *UART0_Init* function is pretty simple. UART0 is forced into Eight-bit Timer/Counter Auto-Reload mode, its baud rate divisor is disabled, and the UART0 transmit-ready bit is set.

The final operation performed by the Configuration Wizard 2 application is to update the *Init_Device* function. Here's what the updated *Init_Device* function looks like now:

```
//-----------------------------------------------------
void Init_Device(void)
{
    Reset_Sources_Init();    // disable the watchdog
    Oscillator_Init();       // set SYSCLK to 49 MHz
    Timer_Init();          // set 8-bit Timer/Counter
                           //  Auto-Reload mode
    Port_IO_Init();        // set UART0 TX and RX pins
                           //  for push-pull
    UART0_Init();          // enable UART0 and set UART
                           //   mode to match Timer 1
}
//-----------------------------------------------------
```

■ FIGURE 7. This is the result of all of our hard work. I'll show you the hardware behind this in the next installment of Design Cycle.



DOES IT REALLY WORK?

I sincerely hope that there was absolutely no doubt in your mind. The Configuration Wizard 2 application can do many wonderful things. However, it can't write your core application code for you. We went to a bunch of trouble to configure our C8051F120 hardware to spit some ASCII characters out of the UART0 transmit pin. So, I've put together a very simple application that sends a message via the UART0 transmit pin and toggles an LED every time the message is sent. Here's the application code behind my madness:

```
//-----------------------------------------------------------
void main()
{
      unsigned int x,y;     // declare local variables
      Init_Device();        // init the microcontroller
      SFRPAGE = UART0_PAGE; // enable UART0 access
      while(1){
        x = 0xFFFF;         // init the kill-time values
        y = 0x007F;
        do{                 // kill some time
          while(--x);
        }while(--y);

        LED = ~LED;         // toggled the LED on P1.6
        printf("\r\nNUTS AND VOLTS READERS ROCK!\r\n");
      }
}
//-----------------------------------------------------------
```

Again, no rocket science here. After declaring a couple of integers for use by a kill-time routine, my little C8051F120 application calls the *Init_Device* function. Recall that the *Init_Device* function does everything necessary to prepare the C8051F120 peripherals and general-purpose I/O pins for pumping stuff out of UART0 and bit twiddling the LED, which is attached to general-purpose I/O pin P1.6. I selected the kill-time delay values to toggle the LED and send a message once every couple of seconds.

Sending a message using UART0 involves writing to the UART0 buffer register SBUF0. We must load the SFRPAGE register with the SBUF0 SFR page so we can address the SBUF0 register within the SBUB0 SFR page. The kill-time routine is a simple *do-while* loop that decrements the x variable from 0xFFFF to zero as long as the y variable has not decremented to zero itself. When all of the integer variables expire to zero, the LED is toggled and a message is emitted from UART0. This is all contained within the braces of an endless loop created by the *while(1)* C statement. I rest my case with Figure 7.

WHERE'S THE HARDWARE?

(Yes, I was tempted to headline this section as "Where's the Beef?") If you've ever taken pilot training, you know that more time is spent on the ground in training than in the air when you begin the process. With that thought, you've done enough ground training with the C8051F120, and in the next installment of Design Cycle, we'll jump into the cockpit of a C8051F120 microcontroller. In addition to examining the C8051F120 hardware, we'll finish off writing some code for the rest of the C8051F120 peripherals. In the meantime, I'll post the C source code and the Configuration Wizard 2 configuration file (nuts_and_volts.cwg) we discussed here on the *Nuts & Volts* website for you.

For those of you that want to get your hands dirty right now, you'll need to get a demo or registered copy of the Keil C51 C Compiler and a Silicon Laboratories USB Debug Adapter to run the code I've presented in this Design Cycle entry. The easy way to do this is to get yourself a Silicon Laboratories C8051F120 Development Kit, which contains a nifty C8051F120-equipped development board, a demo version of the Keil C51 C Compiler, and a Silicon Laboratories USB Debug Adapter. I'll show you how to integrate and use the Keil and Silicon Laboratories tools as we put the C8051F120 hardware through its paces next time around. **NV**

CONTACTING THE AUTHOR

■ *Peter Best can be reached via email at peter@nerdvilla.com.*

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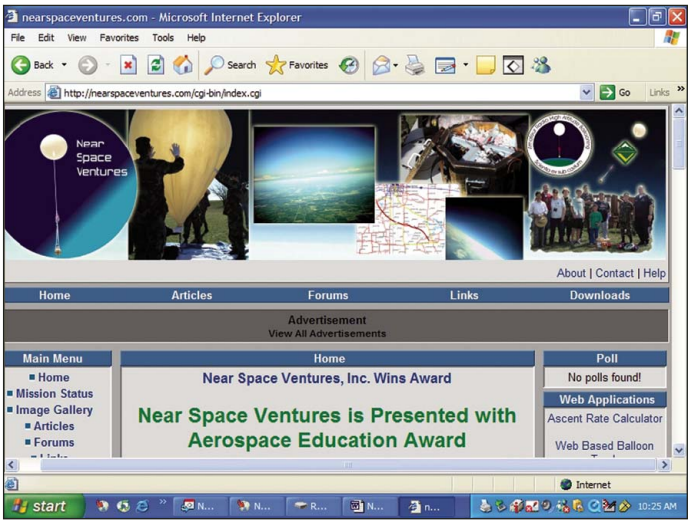
■ BY L. PAUL VERHAGE

THE NEAR SPACE VENTURES WEBPAGE

NEAR SPACE VENTURES IS THE WEBPAGE OF an amateur radio high altitude balloon (ARHAB) and Civil Air Patrol (CAP) organization named CAPnSPACE. CAPnSPACE has developed a great website that I'd like to share with you this month. But first, let me tell you how I met the Campbells, the founders of CAPnSPACE.

■ FIGURE 1



They were attending the Great Plains Super Launch in 2004 — their first near space event — to see how high altitude ballooning was done. Since they had nothing else to do other than watch, I put them to work filling and launching my balloon. (That just goes to show that if I see you hanging around very long, I'll put you to work!) Since then, we've been good friends.

Visit the CAPnSPACE website for reports on their past launches, information on their currently planned launches, and the software tools needed to make near space flight predictions. The part of their website I like best is its selection of online prediction applications. Before I describe how to use those apps, I'll briefly introduce the rest of their website.

The top of their website shows the following convenient links:

• *Home* appears throughout the website and it takes you back to the homepage no matter where you are.

• *Articles* takes you to page that has 15 categories of articles that CAPnSPACE currently maintains. Currently, the only archived articles are in Announcement. That's not surprising since their website is fairly new and CAPnSPACE has concentrated on developing their online applications.

• *Forums* takes you to a discussion board.

• *Links* is currently empty, but ready to network with other valuable websites.

• *Downloads* is a page listing 36 near space presentations.

Below the top row of links are three columns of additional links. I'll describe the important aspects of each column.

In the left column is a series of links to things like Mission Status, Image Gallery, and some of the items already described at the top of the homepage.

• *Mission Status* contains information on the payloads CAPnSPACE is preparing to launch, the frequencies they'll use, and the current weather report.

• *Image Gallery* is a set of folders for each CAPnSPACE mission, project, and workshop, containing photo albums of all of their activities.

In the center column are links to messages. They are brief but you may post your own comment after reading them.

My favorite part of the website is the right column. Here is where you'll find links to their two online flight prediction applications. I go here to make predictions for my near space missions, specifically, the expected flight path and recovery zone. Even if you're not ready to launch a near spacecraft, you should check out these applications — they may encourage you to launch your own near spacecraft!

Making a near space flight prediction at CAPnSPACE is simple. You start by running the Ascent Rate Calculator to determine how fast the near spacecraft will climb. Then you run the Flight Track Prediction Utility to predict the flight path and recovery zone of the mission. If you're not happy with the predicted flight path and recovery zone, you have a few

options. First, you can cancel the launch and reschedule it for next week (I don't like this one). Second, you can change the amount of helium inside the balloon to change its climb rate and maximum altitude. Or third, you can move to a new launch site. Let's look at each program in more detail.

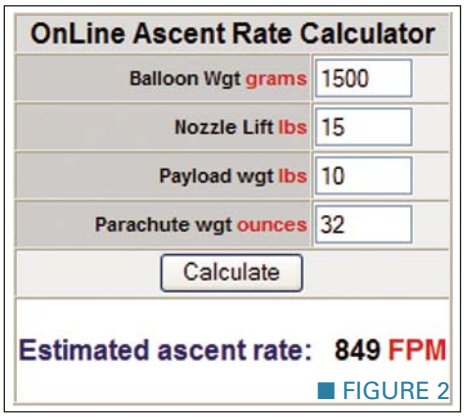


FIGURE 2

THE ASCENT RATE CALCULATOR

The first ascent rate calculator program was written by Hank Riley. His program calculated the maximum altitude and climb rate for a balloon given its type, initial fill of helium, and payload weight (which you can find at the Edge of Space Science website at **www.eoss.org**)

When you run the CAPnSPACE version of the Ascent Rate Calculator, you're presented with the screen shown in Figure 2.

The *Balloon Wgt* field asks for the size of the balloon. When you purchase a weather balloon from Kaymont (**www.kaymont.com**), you order it by weight. Examples of the balloons I've flown in the past are 300, 1,000, 1,200, 1,500, and 3,000 grams. The weight of the balloon (grams is actually a measure of mass and not of weight — but we'll ignore that) is an indication of the balloon's maximum volume and the altitude it can reach before bursting.

The *Nozzle Lift* field asks how much lift the balloon will have after being filled. The greater the lift of the balloon, the faster the balloon will climb. At the same time that its ascent rate is greater, its maximum altitude is lower, but only slightly. A lift of three pounds greater than the payload weight is my minimum preferred amount of lift.

The *Payload Wgt* field asks for the weight of the near spacecraft sans parachute. In most cases, this won't be greater than 12 pounds. You can launch a payload heavier than 12 pounds, but additional rules will apply to your launch. Check Federal Aviation Regulation 101 (FAR 101) for the additional requirements. You can consult my book — *Near Space* (available from Parallax; **www.parallax.com/html_pages/resources/custapps/app_nearspace.asp**) — for its chapter on FAR 101 or consult with other ARHAB groups.

The *Parachute Wgt* field asks for the weight of the parachute in ounces.

Click the *CALCULATE* button to calculate the *Estimated Ascent Rate* based on your values. Remember this ascent rate, because it's one of the inputs to the next program, Balloon Track. Just a note here — the minimum ascent rate I accept for a flight is 1,000 feet per minute. When the ascent rate is too low, there's a chance the balloon will become neutrally buoyant and stop rising. In a future article, I'll explain how you can prevent this from ruining your near space mission.

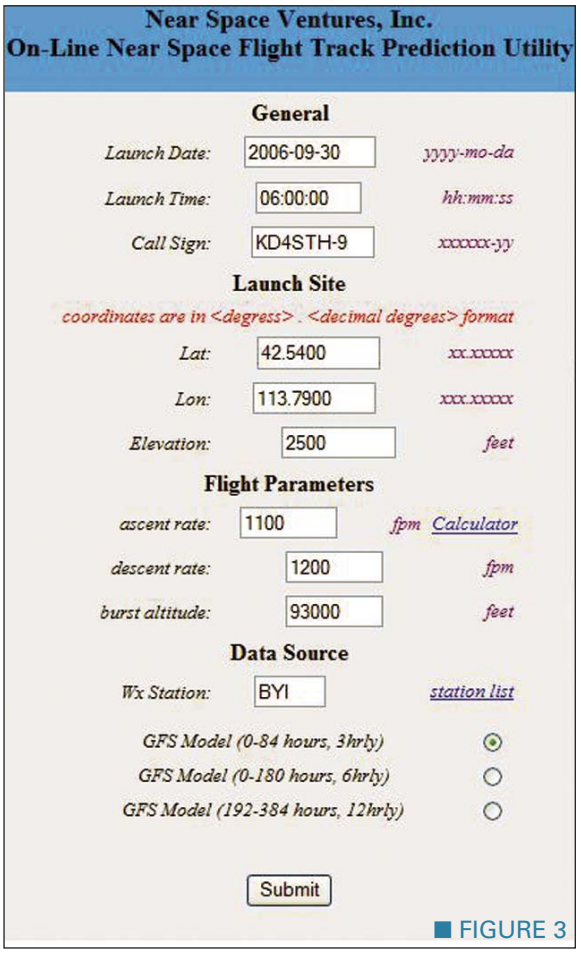


FIGURE 3

WEB BASED BALLOON TRACK

Balloon Track has a long history in the ARHAB community. It was originally written by Bill Brown as a Basic program that ran under MS-DOS (remember that operating system?). Later, Rick Van Glahn of Edge of Space Science in Denver rewrote Balloon

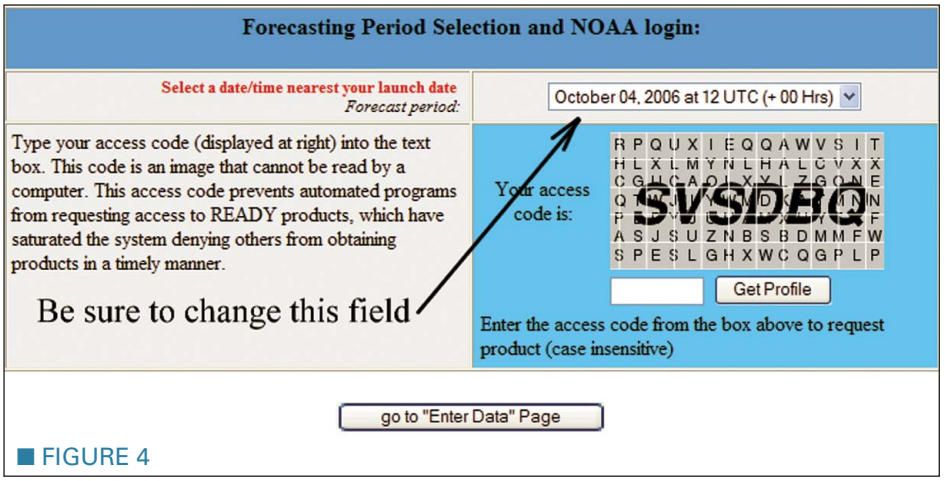
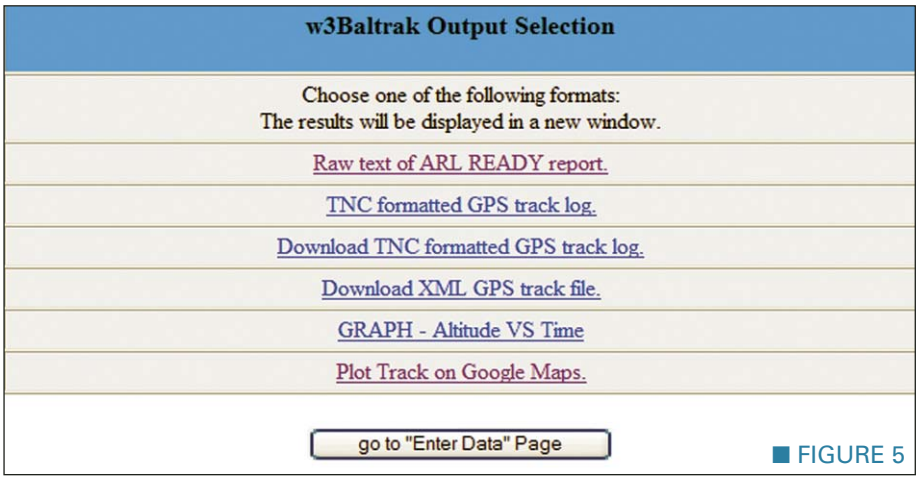


FIGURE 4

NOTE

The maximum altitude that a near spacecraft will reach is influenced by the weight of the near spacecraft, the original volume of helium in the balloon, and variations in the balloon's manufacture. So the numbers I've given you are just rough estimates. You can experiment with changing lift amounts and payload weights with a program called LiftWin. This program is available from the website of the Edge of Space Science (**www.eoss.org**) as a free download.



■ FIGURE 5

Track as a Windows application. Now, Troy Campbell has created an online version of the software that takes you through the entire process of making a flight prediction (see Figure 3).

Currently, you don't have to enter information in the General section. In the future, you'll want to enter this information because of the planned enhancements to the application.

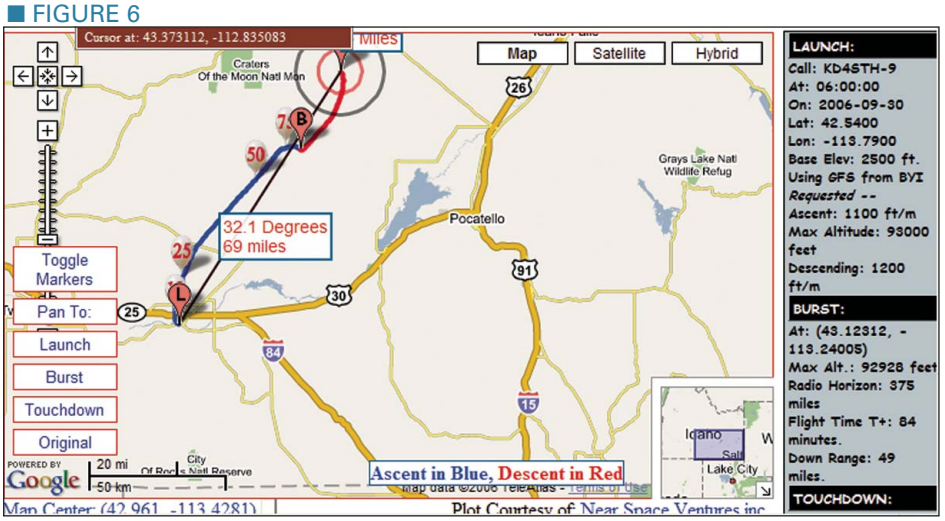
The *Launch Site* section asks for the latitude and longitude of the planned launch site. This information is used to map the mission's predicted flight path and recovery zone. The elevation field is not very important because the effects of launch elevation are usually swamped by inaccuracies in the predicted winds aloft, precision of the balloon's helium fill, and manufacturing variations in the balloon. One exception may be when the balloon is launched from the top of a tall mountain.

The *Flight Parameters* section asks for the predicted ascent rate, descent rate, and burst altitude of the balloon. Here's where you need the result from the Ascent Rate Calculator. In my experience, the descent rate is between 1,000 and 1,200 feet per minute. If the parachute is larger or the payload lighter, the descent speed is lower. You'll get a better feel for the proper descent rate after you've flown a mission or two. As a rule of thumb, I expect to reach 50,000 feet with a 300 gram balloon, 80,000 feet with a 1,000 gram balloon, 85,000 feet with a 1,200 gram balloon, 93,000 feet with a 1,500 gram balloon, and over 100,000 with a 3,000 gram balloon (see the note in the sidebar).

There's one data entry field and three buttons in the *Data Source* section. The *Wx Station* (weather station) field asks for the station ID for the weather station closest to your launch site. Since very few people know the three letter designation of their local weather station, there's an option to look it up in the *Station List* link. You'll find weather stations sorted by state and listed in alphabetic order. Next to each weather station is its three letter designation. I discovered that the Boise weather station has a station ID of BOI.

After entering the station's ID, click one of the three buttons below the *Wx Station* field.

■ FIGURE 6



■ FIGURE 7

Each button selects a particular weather model to use for the flight prediction. There are lots of weather models developed by meteorologists, but the ones the ARHAB community likes best are the GFS models. They're based on current weather observations, including data from radiosonde launches. GFS models are updated periodically, depending on how short-term their predictions are.

If the launch is between eight and 16 days away, then select the 12 hour model (as its name indicates, this model is updated every 12 hours). If the flight is between three and eight days away, then select the six hour model. If the flight is less than 3-1/2 days away, then select the three hour model.

Now click on the *Submit* button at the bottom of the page. The next webpage to appear is from READY, a database of (perhaps all) meteorological models (see Figure 4).

First, update the time and date of the launch. By default, READY displays the most current time and date. So if you forget to update this field, the predictions will be in error. The time and date drop-down menu is located at the top right of the page (I've pointed it out in my graphic). The time and date are given in UTC which is several hours later than the current US time. (See the sidebar for how to convert your current time to UTC.)

To prevent software bots from downloading READY data so frequently that it denies the rest of us data, you must manually verify that you're a human by typing the characters displayed in the *Access Code* field. Now click on the *Get Profile* button and wait. The Online Balloon Track software collects the data file from READY, so you don't have to copy the data yourself. When the READY data has been received, Balloon Track returns back to Near Space Venture's Output selection screen.

Now you get to select how to display the flight prediction. I recommend the *Plot Track on Google Maps* option. When you select this option, you get a Google Map with an overlay of the near spacecraft's predicted flight path (see Figure 6).

On the map, the ascent portion of the flight is colored blue and the descent portion is red. The map is a simple one showing roads, towns, lakes, and rivers. You can zoom into the map for more detail. Next, try selecting the *Satellite* button at the upper right of the screen. This display is an overlay of the near spacecraft's flight path on an aerial image. That gives you a much better idea of the terrain your balloon will recover in. Finally, select the *Hybrid* button for a map with the roads, satellite image, and flight path of the near spacecraft (see Figure 7).

So now you have a map, what next? Take a close look at where the balloon is predicted to land. Is the recovery zone located in or near towns, lakes, or forests? All those make for a difficult recovery. If the recovery zone looks difficult, remember you can change the balloon's initial volume of helium or change the launch time and place. Be sure to run the prediction again if you change something.

Now a word of warning. The prediction of a near space flight is not an exact science. So be sure to look around the recovery zone for areas that you want to stay out of. It's best if you make a few more predictions with changes in the ascent rate and burst altitude. The collection of recovery locations gives you a better idea of the recovery zone than a single prediction will. If the recovery zone looks good, then you probably have found an ideal flight. It's all pretty cool, isn't it? If you're interested in near space missions and you're located near eastern Kansas, then contact CAPnSPACE. They'd be pleased to help you. Be sure you tell them that Paul from *Nuts & Volts Magazine* sent you!

Onwards and Upwards,
Your Near Space Guide **NV**

UTC CONVERSIONS

■ In the Eastern Time zone, add five hours to the planned launch time.

■ In the Central Time zone, add six hours to the planned launch time.

■ In the Mountain Time zone, add seven hours to the planned launch time.

■ In the Pacific Time zone add eight hours to the planned launch time.

If you're in a part of the country that obeys daylight savings time (summer time), add one hour less (or four hours for Eastern, five hours for Central, six hours for Mountain, and seven hours for Pacific).

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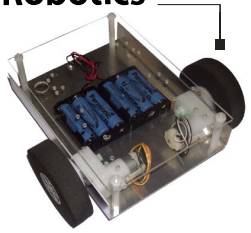
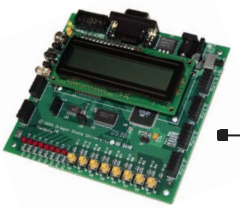
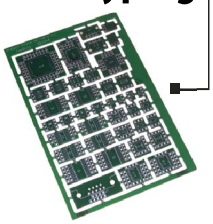


Microcontrollers



Prototyping



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■ BY CHUCK HELLEBUYCK

8/14/20-PIN PIC® MICROCONTROLLER FAMILY

PROGRAMMING PIC® MICROCONTROLLERS (MCUs) has been my hobby and sideline for many years. In fact, I started back when there were only five PIC MCUs to choose from. Now there are hundreds of different PIC MCUs. I've helped thousands get started programming PIC MCUs through my books, articles, and development boards, and have enjoyed every minute of it.

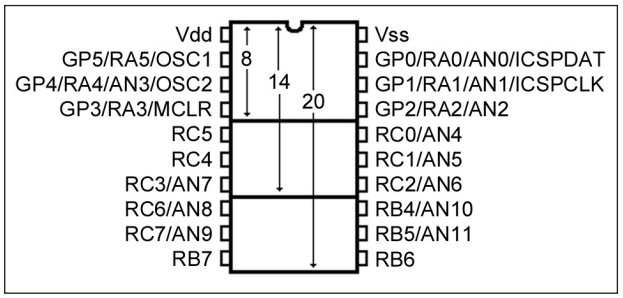
Outside of this activity, my professional electronics career (that pays the larger portion of my bills) has always been in the automotive electronics industry, and I've learned a lot about designing electronics in this harsh environment. Change is inevitable and I recently was offered the chance to join Microchip as a Field Applications Engineer, so I made the move. This should give me even more information to draw from for these articles, but my focus for this column is and always will be to help beginners, hobbyists, and anybody else learn how to get started programming PIC MCUs.

Before I joined Microchip, I hadn't used the 14-pin or 20-pin PIC MCUs at all. In fact, I think I only had one in my storage cabinets, which are full of PIC MCUs. The 14-pin and 20-pin PIC MCUs are cousins to the eight-pin PIC MCUs that help make up the full line of low pin count devices. They all share the same Vdd, Vss, Data Clock, and MCLR connections that are needed for programming, which I only realized during the development of my EZPIC programmer.

I originally had an eight-pin socket, and then I changed it to a 14-pin socket when I realized they could share. After getting feedback from a customer who had successfully programmed a 20-pin PIC MCU by putting it in the 14-pin socket, I modified the design to replace the 14-pin with a 20-pin socket. I'm just in the process of getting those boards manufactured, because I had to wait until the previous version was sold out.

COMMON PINOUT

I did the design work on my EZPIC programmer before joining Microchip, but never fully realized how handy having those common pinouts was until I started playing with them. Because I had easy access to some of these parts at Microchip, I began using them with Microchip's PICkit™ 2 programmer, which I've talked about here before. The PICkit 2 starter kit comes with a 20-pin socketed development board. I began by programming various eight-, 14-, and 20-pin PIC MCUs to better understand all of the features these parts offered. I soon appreciated how I could build sample programs using the various parts from eight-, 14-, and 20-pin PIC MCUs without having to change the development board. This was the result of the common pinout between these parts. Figure 1 shows the common pin layout.



■ FIGURE 1. The common pinouts of eight-, 14-, and 20-pin PIC MCUs.

Notice how the 20-pin parts have up to 12 A/D ports. There is a lot packed into these parts, so I left off some of the pin descriptions — such as the comparator pins and the T1G pin designation for the Timer1 gate. This is a relatively new feature on PIC MCUs that allows you to turn the internal clock feed to Timer1 on or off, based on an external signal. You can set it to allow the internal clock feed to run on a high pulse and turn off on a low pulse. This way, you can use Timer1 to easily measure pulse width in the background while your program is doing something else. This will definitely be a feature I'll talk about in a future article.

My January '07 column on using the PIC12F675 as a 555 replacement was popular, based on email feedback. Apparently, a lot of people like those little eight-pin devices. Now I realize that starting with an eight-pin PIC MCU lays the groundwork for a smooth upgrade path. If you plan ahead and lay out your circuit board for a 20-pin PIC MCU, you can just drop in a 14-pin or eight-pin PIC MCU in the same socket without

issue. You can use the extra I/O on the 20-pin part for functions you will only use occasionally. All of these parts offer the internal oscillator plus the internal MCLR option, so all you really need to hook up is Vdd (2.0-5.5V) and Vss (ground) to bring the PIC MCU to life.

EXTRA FEATURES

Some of you may be reading this and saying, "Duh, where have you been? We've known about these parts." Sorry if I'm telling you something you already knew, but I was surprised to find how many advanced features these parts have. One of them is the Enhanced Capture and Compare PWM (ECCP) peripheral that is great for designing a motor-control application. Figure 2 shows a sample setup direct from the data sheet. My layout in Figure 1 doesn't show the P1A through P1D pins, but you can easily find them on the data sheet.

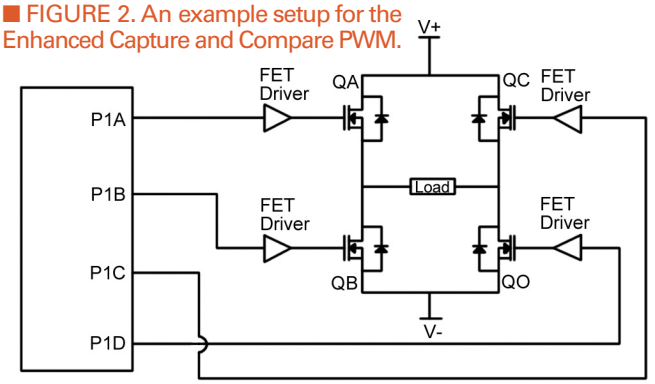
I hope to cover more on this peripheral in the future article, as I know motor control interests a lot of people. The nice thing about this peripheral is it handles all the timing and even the dead-time delay required, so you don't ever have two FETs on at the same time causing a short. This can happen when one FET is shutting down slowly while the other starts up quickly, causing the temporary short.

These parts also have internal comparators and even share some of the same A/D connections, shown as all the ANx pins in the layout of Figure 1. I really have to look at these parts for future home projects, because they have some of the latest and greatest PIC MCU features. They even have an LIN peripheral in some of the parts, which is a communication bus that is growing in popularity within the automotive world. Again, maybe you knew about all this but I just wanted to show that even an old-timer like me can work with PIC MCUs for years and still discover new stuff.

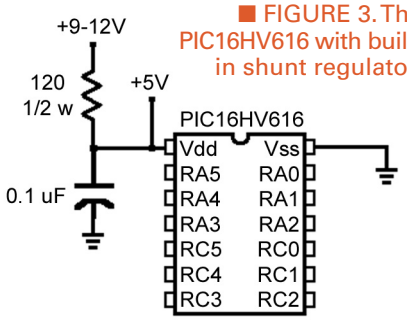
HIGH-VOLTAGE (HV) PIC MCUs

Through this discovery phase, I also was introduced to a couple of new 8/14-pin family members — the PIC12HV615 and PIC16HV616 — which are newly released. These are Flash-based PIC MCUs, but they have a built-in shunt regulator (which is a fancy term for a zener diode). This means they can run off of a higher voltage without needing an external regulator. Figure 3 shows a schematic for a PIC16HV616 with the shunt regulator series resistance and capacitance in place. I'm not showing the MCLR pull-up or the oscillator, since these would be set to internal operation.

■ FIGURE 2. An example setup for the Enhanced Capture and Compare PWM.



■ FIGURE 3. The PIC16HV616 with built-in shunt regulator.



The key to using this part is setting the proper series resistance and capacitance. There are three formulas for calculating those values, depending on the current and voltage range you need to work with. I've found that you either have a large voltage range or a large current range, but not both at the same time. For example, I chose to use a voltage input of nine to 12 volts. This limits how much current range I can have. I limited my current variation to 20-25 ma. If I go above or below this, the shunt regulator will be out of its design limits. Most people can set their design to a fixed voltage input, which gives you a greater current range to work with. The equations are listed below as Equation 1, 2, and 6, which I pulled from the Microchip application note AN1035 and you can download from **www.microchip.com**.

EQUATION 1:

$$R_{MAX} = \frac{(V_{U_MIN} - 5.0)}{1.05 \cdot (I_{LOAD_MAX} + 4\ mA)}$$

EQUATION 2:

$$R_{MIN} = \frac{(V_{U_MAX} - 5.0)}{0.95 \cdot (I_{LOAD_MIN} + 50\ mA)}$$

EQUATION 6:

$$C_{MAX} = \frac{42\ MS}{R_{SER} \cdot ln\left(\frac{2.1}{5.0}\right)}$$

Equation 1 gives us the upper limit of the series resistance. Using the lower end of our voltage range and the upper end of our current range, we get the following:

Rmax = (9V – 5V)/1.05 (25ma + 4 ma)
Rmax = 131 ohms

Equation 2 gives us the lower limit of the series resistance.

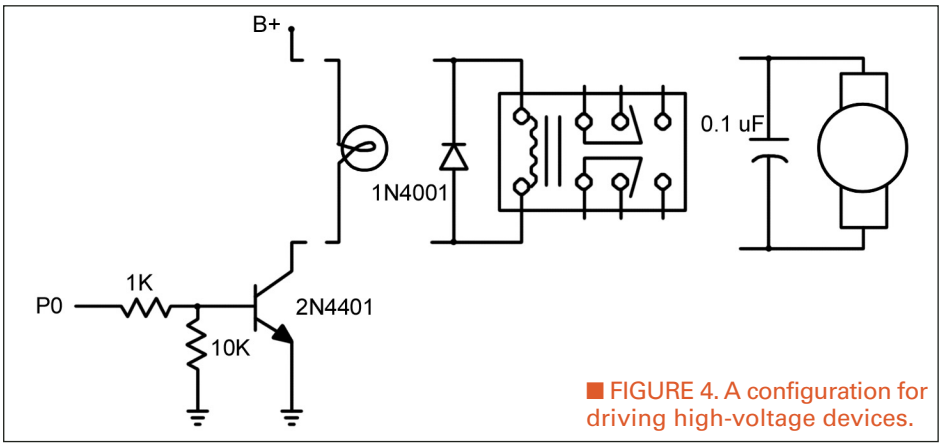
Rmin = (12V – 5V)/0.95 (20ma + 50 ma)
Rmin = 105 ohms

With this, I select a value of 120 ohms that falls within the two limits. But, I need to calculate the power rating of the resistor. Since the top of the resistor can see a maximum of 12V and the bottom will see the regulated 5V, the power is found with the equation:

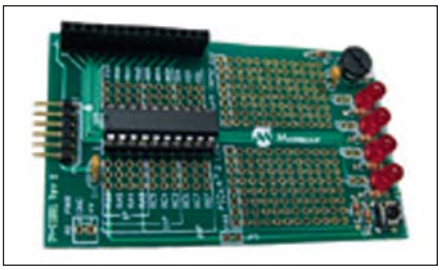
Rpwr = (12V – 5V)^2 / 120 ohms
Rpwr = 0.4 Watts

Therefore, I'll use a 1/2 W resistor.

Now I have to calculate the capacitor. The data sheet states the capacitor needs to be larger than 0.047 µF for noise suppression, and less than the calculated capacitance of Equation 6. So, putting the values in the equation gives us the following:



■ FIGURE 4. A configuration for driving high-voltage devices.



■ FIGURE 5. Microchip's DM164120-1 development board.

Cmax = 42/[120 * ln (2.1/5.0)]
Cmax = 0.4 µF

Therefore, I chose a value of 0.1 µF — since it's greater than 0.047 µF and less than 0.4 µF. We now have our PIC MCU regulator ready to go. One thing to note with this type of setup is the amount of current a shunt regulator draws without anything happening. The shunt regulator will draw 4 mA, even if the PIC MCU is in sleep mode and nothing else is connected. This is not an ideal setup for battery-operated devices that need long life. For those devices, you could use the PIC16F616 version of this same part, with an external low quiescent current draw regulator.

The HV parts are really handy, though, for applications that need a small component count. I've seen motors with the HV part built into the back of the motor. This may be a great way to make a serially controlled motor — similar to a serially controlled LCD module. (That also may be the focus of a future article.)

What I like most about these parts is the ability to run them off the same voltage source as the outputs you may be trying to drive. For example, back in the November '06 column, I showed some hardware interfaces to the PIC MCU. One of them showed how to drive some high-voltage devices using a bipolar transistor, as shown in Figure 4.

I don't specify a voltage here, but instead just state B+. What if that was 12 volts, instead? Using the resistor and capacitor values I calculated above, I could control one of these outputs while also powering the HV PIC MCU from the same supply. Now, this will require some better filtering to prevent the large voltage line from dipping quickly when the load kicks in, possibly resetting the PIC MCU. But, that may be easily solved if the load is fairly clean. This does offer a simpler solution than trying to add a separate voltage regulator.

DEVELOPMENT SUPPORT

As I mentioned, Microchip's PICkit 2 programmer supports these parts. So does the latest version of my PICBasic Pro compiler — except for the PIC12HV615, which has just recently been released to the public. This is the eight-pin version of the PIC16HV616, so it's got its own set of great applications. Can you imagine that part in a small surface-mount SOIC package without the need for a regulator?

I can already think of several applications where that could be squeezed into a tight sensor package. It could use an A/D port to read the sensor element and then send the value back via a one-wire serial connection. This

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could reduce the connections in a common 12V setup to Power, Ground, and Serial Signal, and not take up much space at all. Interesting, isn't it?

Now, build up your own development board with a 20-pin socket and you have a setup complete for 20-, 14-, and eight-pin development. Better yet, check out the DM164120-1 development board package at **www.microchipDIRECT.com**. It's shown in Figure 5 and is really a great deal. You get one populated board and two blank boards for $23.99. That's about $8 per board, and it has the serial programming port already wired in.

Another great board is the PICPROTO20 from microEngineering Labs (melabs.com), shown in Figure 6. This board has all the circuitry set up for a voltage regulator, external crystal, and MCLR pull-up resistor. It even includes a header that matches their programmers for In-Circuit Serial Programming™ (ICSP). They retail for $12.95 each, so it's not a bad way to develop with this family of PIC MCUs.

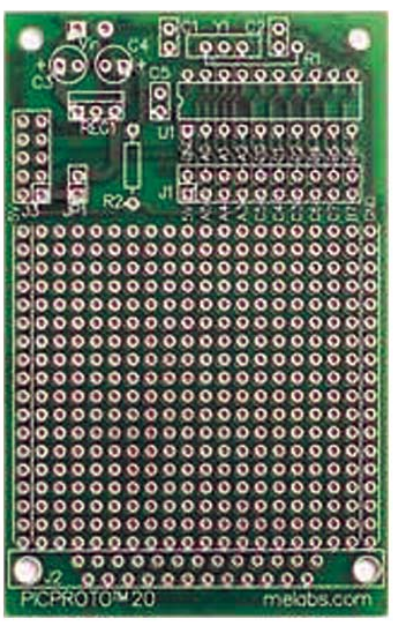
CONCLUSION

I promise more projects in the near future, and some of them will include these smaller PIC MCUs. I just wanted to let you know what's out there, as you gather the pieces you need for your next PIC MCU project. I just cannot believe how easy it is getting to create unique items with a PIC MCU. I'm constantly thinking of new applications and projects, but keep running out of time to get them into a decent format for these columns. This is why I can honestly say more projects are coming, as they are sitting on my bench half complete. If you have a particular project idea you want me to consider, shoot me an email at chuck@elproducts.com, and please stop by my website at **www.elproducts.com**.

I am working on improving it with more information for visitors. I'm finding all kinds of useful links as I help Microchip customers solve their design challenges. Some of the links are just hard to find on the Microchip website. Hopefully, I can put links to them on my website so you have a one-stop place to easily find what you need.

Until next month, keep on having fun with those PIC MCUs. **NV**

■ FIGURE 6. The PICPROTO20 from microEngineering Labs.



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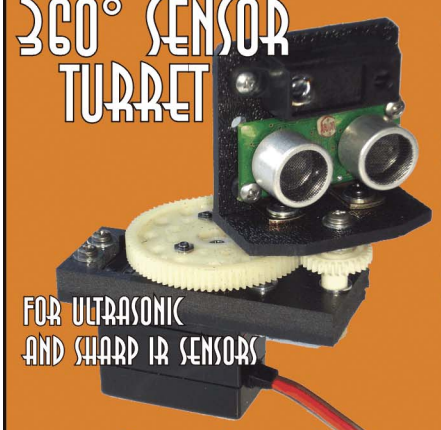

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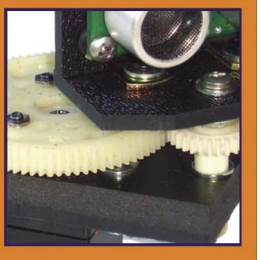

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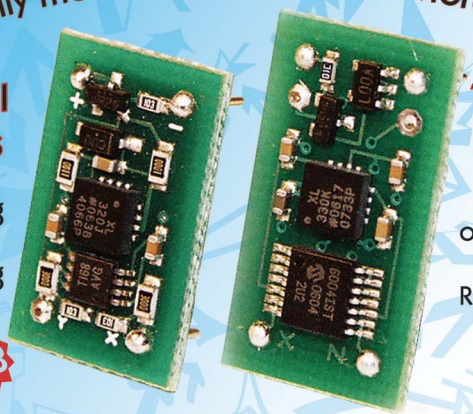

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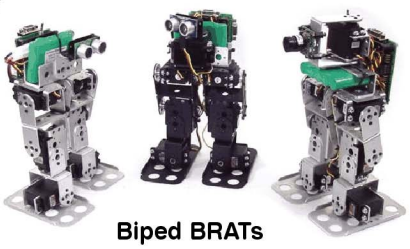

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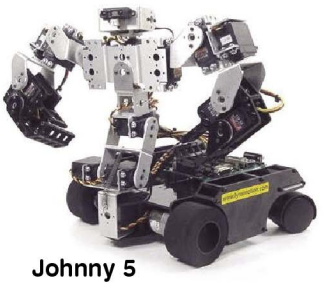

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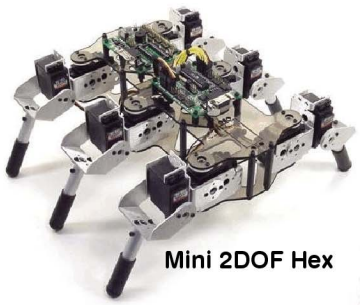

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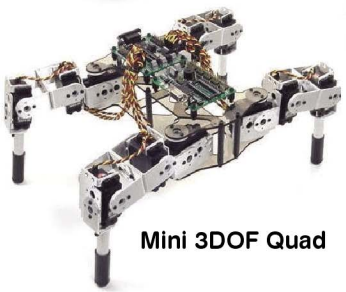

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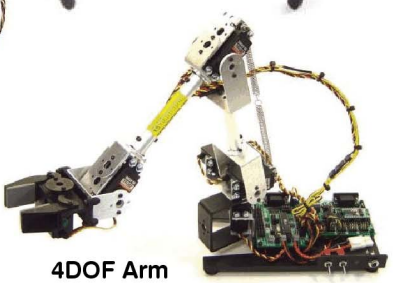

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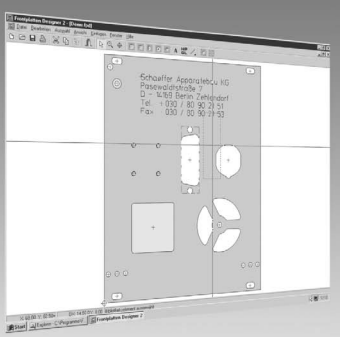

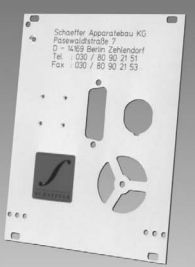

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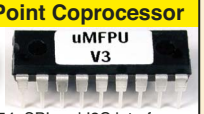

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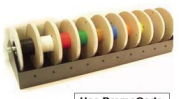
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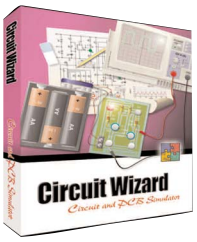

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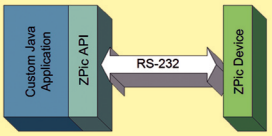

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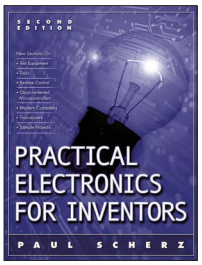
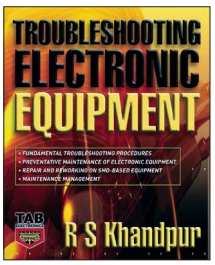
ELECTRONICS

Practical Electronics for Inventors
by Paul Scherz



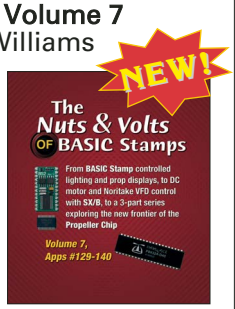
This intuitive, applications-driven guide to electronics for hobbyists, engineers, and students doesn't overload readers with technical detail. Instead, it tells you — and shows you — what basic and advanced electronics parts and components do, and how they work. Chock-full of illustrations, *Practical Electronics for Inventors* offers over 750 hand-drawn images that provide clear, detailed instructions that can help turn theoretical ideas into real-life inventions and gadgets. **$39.95**

Troubleshooting Electronic Equipment
by R. S. Khandpur



From cell phones to medical instruments to digital and microprocessor based equipment, this hands-on, heavily illustrated guide clearly explains how to troubleshoot, maintain, and repair all types of electrical equipment. The author covers all the essentials such as necessary tools, soldering techniques, testing, fundamental procedures, and mechanical and electrical components. **$49.95**

Nuts & Volts of BASIC Stamps — Volume 7
by Jon Williams



Nuts & Volts of BASIC Stamps, Volume 7 includes articles #129-140 from *Nuts & Volts Magazine*. In this 2006 collection, BASIC Stamp 1, BASIC Stamp 2, SX/B, and Propeller programming are explored in a series of real-world applications. This book is useful for the *Nuts & Volts* reader, newcomers to BASIC Stamp, SX, and Propeller microcontroller projects, and seasoned programmers looking for new ideas. **$14.95**

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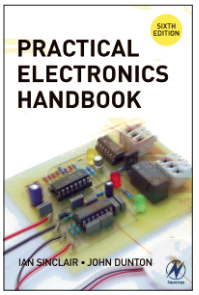
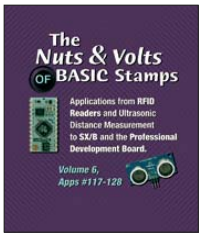
Practical Electronics Handbook: Sixth Edition
by Ian Sinclair/John Dunton



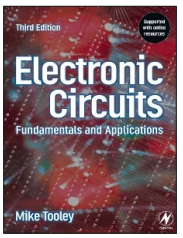
Ian Sinclair's *Practical Electronics Handbook* combines a wealth of useful day-to-day electronics information, concise explanations, and practical guidance essential to anyone involved in electronics design and construction. The collection of key data, fundamental principles, and circuit design basics provides an ideal reference for a wide range of students, enthusiasts, technicians, and practitioners of electronics who have progressed beyond the basics. The sixth edition is updated throughout with new material on microcontrollers and computer assistance, and a new chapter on digital signal processing **$39.95**

Nuts & Volts of BASIC Stamps — Volume #6
by Jon Williams



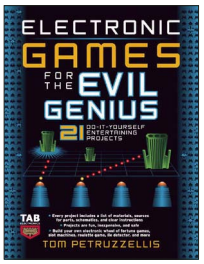
Nuts & Volts of BASIC Stamps — Volume 6 includes articles #117-128, written for 2005. Article topics consist of RFID Readers and Ultrasonic Measurement, SX/B and the Professional Development Board, the advanced MIDI receiver, programming the SX microcontroller in BASIC, mastering the MC14489 display driver, and more! The Nuts & Volts of BASIC Stamps books are a favorite Parallax technical pick and are a tremendous technical resource for all PBASIC programming projects. **$14.95**

Electronic Circuits — Fundamentals & Applications: Third Edition
by Mike Tooley



In *Electronic Circuits*, Mike Tooley provides all the essential information required to get to grips with the fundamentals of electronics, detailing the underpinning knowledge necessary to appreciate the operation of a wide range of electronic circuits, including amplifiers, logic circuits, power supplies, and oscillators. The third edition now offers an even more extensive range of topics, with extended coverage of practical areas such as circuit construction and fault finding, and new topics including circuit simulation, electronic CAD, and a brand new chapter devoted to the PIC microcontroller. **$34.95**

Electronic Games for the Evil Genius
by Thomas Petruzzellis



You can have a wicked amount of fun on your way to becoming a game master! In *Electronic Games for the Evil Genius*, popular how-to author Tom Petruzzellis gives you everything you need to build 35 exciting games and gadgets. You get complete, easy-to-follow plans, with clear diagrams and schematics, so you know exactly what's involved before you begin. Packed with fun projects that you'll love to build and play with, this guide develops game expertise one simple step and project at a time. **$24.95**

Electromechanical Devices & Components Illustrated Sourcebook
by Brian Elliott

Master the key elements of electromechanical components. Essential to the design, repair, or operation of your electromechanical devices, this quick-find reference provides illustrations, descriptions, and relevant calculations for 2,000 time-tested electromechanical components. **$89.95**

PROJECTS

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by Dave Prochnow

The sky is not the limit! If you yearn to touch the stars, *101 Outer Space Projects for the Evil Genius* has everything you need to explore the universe from the comfort of your own home. Whether you're a beginner stargazer or a more experienced astronomer, you'll find an outstanding project to satisfy you, from model rockets and celestial maps to space robots, GPS systems, and much, much more. Full of easy-to-follow plans and clear schematics for each project, as well as lists of materials and tools so you know exactly what's involved before you begin. **$24.95**

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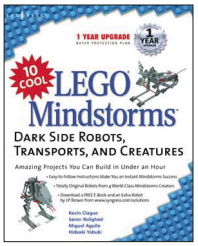
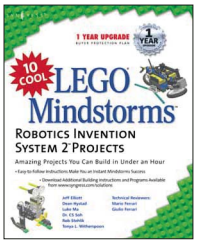


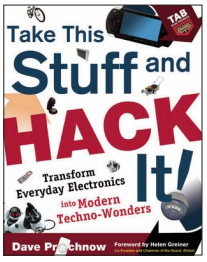
The Dark Side Developer's Kit is targeted towards the young or novice LEGO MINDSTORMS designer, age 9 and up, although experienced MINDSTORMS fans will appreciate the unique possibilities offered by this kit. as well. *The Dark Side Developer's Kit* includes special MINDSTORMS pieces that allow the user to create a host of Star Wars themed robots, creatures, and vehicles. It also comes with the Micro Scout, a mini-computer with seven built-in programs, a motor, and a light sensor that brings the MINDSTORMS creations to life with a minimum of effort. **$24.95**

10 Cool LEGO Mindstorm Robotics Invention System 2 Projects



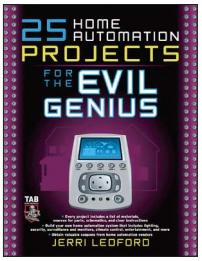
The LEGO MINDSTORMS RIS 2.0 is the core set for all MINDSTORMS users, that lets users design and program working robots — limited only by their imagination. Initially designed for users 12 and up, LEGO MINDSTORMS has taken off with LEGO enthusiasts of all ages. *10 Cool LEGO MINDSTORMS RIS 2.0 Projects: Amazing Projects You Can Build in Under an Hour* provides step-by-step instructions and detailed illustrations for users of all skill levels and proficiencies. **$24.95**

Take This Stuff and Hack It!
by Dave Prochnow



Transform common household items into really cool stuff. You don't need to be an electronics genius to get started turning everyday items into high-performing wonders. With how-to guru Dave Prochnow's step-by-step directions and fully illustrated plans, even beginners can hack their way to a high-tech home, cooler toys, and less yard work. Certain to fire your imagination and start you plotting new, original, and even more creative wonders you can make from ordinary household items, *Take This Stuff and Hack It!* is the perfect gift for your inner inventor. **$27.95**

25 Home Automation Projects for the Evil Genius
by Jerri Ledford



Computer technology has caught up with home automation, and it's now easy and inexpensive to automate everything in a house — including lighting, security, appliances, entertainment, and environmental conditions — and here's how to do it! This well-illustrated resource offers 25 complete home automation projects that require only basic household tools and the instructions found within its pages. **$24.95**

NEW 2006 CD-ROMS!

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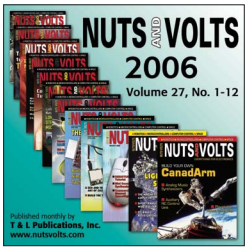


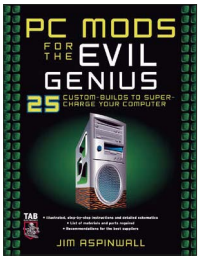
Here's some good news for *Nuts & Volts* readers! Along with all 24 issues of *Nuts & Volts* from the 2004 and 2005 calendar years, the 2006 issues are now available, as well. These CDs include all of Volumes 25, 26, and 27, issues 1-12, for a total of 36 issues (12 on each CD). These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **$24.95 – Buy 2 or more at $19.95 each**

SERVO CD-ROM

Are you ready for some good news? Along with the first 26 issues of *SERVO Magazine*, all issues from the 2006 calendar year are now available, as well. These CDs include all of Volume 1, issues 11-12, Volume 2, issues 1-12, Volume 3, issues 1-12, and Volume 4, issues 1-12, for a total of 23 issues all together. These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **$24.95 – Buy 2 or more at $19.95 each**

HOME COMPUTERS

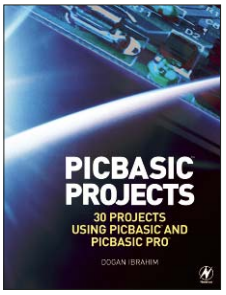
PC Mods for the Evil Genius
by Jim Aspinwall



If you yearn for the coolest, most crazed 'puter around, *PC Mods for the Evil Genius* is the key to the kingdom! This book shows you how to supercharge your PC and create a jaw-dropping system that cannot be purchased off any shelf, anywhere! You get complete, easy-to-follow plans, clear diagrams and schematics, and lists of parts and tools, so you know what's needed before you begin. **$24.95**

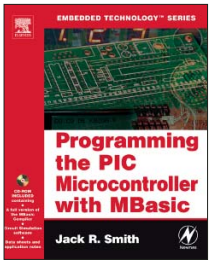
MICROCONTROLLERS

PIC Basic Projects
by Dogan Ibrahim



Covering the PIC BASIC and PIC BASIC PRO compilers, *PIC Basic Projects* provides an easy-to-use toolkit for developing applications with PIC BASIC. Numerous simple projects give clear and concrete examples of how PIC BASIC can be used to develop electronics applications, while larger and more advanced projects describe program operation in detail and give useful insights into developing more involved microcontroller applications. **$29.95**

Programming the PIC Microcontroller with MBASIC
by Jack Smith



No microcontroller is of any use without software to make it perform useful functions. This comprehensive reference focuses on designing with Microchip's mid-range PIC line using MBASIC, a powerful but easy to learn programming language. It illustrates MBASICs abilities through a series of design examples, beginning with simple PIC-based projects and proceeding through more advanced designs. **$59.95**

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Note: We have been told recently that in order to use this transmitter as a primary control, it is necessary to use a micro controller module to split and amplify the received signal into six individual channels.
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All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

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To be considered, all questions should relate to one or more of the following:

1. Circuit Design
2. Electronic Theory
3. Problem Solving
4. Other Similar Topics

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>>> QUESTIONS

I wish to implement a MIDI volume control. I have not found a suitable commercial product that does this other than very expensive digital effects modules. I wish to control the volume or gain of a stereo signal using MIDI expression, which is general MIDI controller number 11.

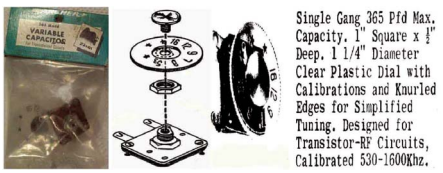
So far, I found a kit which converts MIDI controller levels to a control voltage. I also found a dual voltage controlled amplifier kit. But the MIDI to control voltage module responds only to controllers number 1 through 8; and I need number 11. I found a MIDI module that would convert one message to another (e.g., controller 11 to the range 1-8), but all together this is quite an expense.

#5071 **Richard B. Ahlvin**
Vicksburg, MS

I need an instruction diagram to help make a photo cell dusk-to-dawn unit capable of a 20-1,500 watt 12-36 volt DC application in a small size (8-9 mm deep x 15 mm in diameter circular) that I can encapsulate to make waterproof.

#5072 **Ian Osborn**
via email

Can anyone help me locate a source for 365 Variable Capacitors which RadioShack used to sell as catalog number 272-1431 and used to be incorporated in their Science Fair kits — I've tried eBay but the sellers want too much for it!.



#5073 **Don**
via email

I have two lead-acid batteries, never used but two years old that won't take a charge. I'm sure that they became sulfated from sitting in a no charge condition. Is there a circuit I can construct to desulate them?

#5074 **Jack Riggs**
Reno, NV

I have a couple of old 7.2V battery operated drills sitting around doing nothing and have often had a woodwork project where I'm using a couple of bit sizes, countersink, and maybe a screwdriver. At such times, a few extra drills would be useful. I have just rigged up a rectified DC power supply from an old transformer to run them. They're a bit slow but it will do for now. Anyway, this might make up a simple project for *N&V*. My transformer is 120/6.3CT which gives 9Vrms at the DC end. With the drill running, I read 6.7VDC @ 1.8A and loaded I read 5VDC @ 5A.

I haven't bothered with the center tap of the original battery circuit

although this explains why one battery was always going flat. The first is always switched in, the second only on high speed.

I used an old power cord for the cable using the green wire for the center tap in case I add a 3.6V supply sometime. I'm wondering what I might use for a connector (having removed the three-pin AC). I have lots of four-pin HD connectors from my PC dissassemblies.

#5075 **David Whiteley**
via email

>>> ANSWERS

[#2071 (1-3) - February 2007]

I am a member of an Old Order Mennonite Church. We do not use PCs, TVs, or the Internet, therefore, I have three somewhat unusual requests.

1) *Is it possible to program microcontrollers without a PC? Is any family of microcontrollers better suited for non-PC programming? Are there any books that would help?*

2) *Is there any stand-alone RS-232-C Terminals available anymore? I need one to program my late 80's Premier 2460 phone system. Could one also be used to program microcontrollers? Can someone tell me how to build one? I would prefer one that has a small QWERTY keyboard and an alpha-numerical LCD screen. The phone manual mentions a TI Silent 700 programming terminal.*

3) *How can I send/receive email using my fax machine?*

#1 Taken together, your self-described "three somewhat unusual requests" raise several intriguing considerations and solutions given your Old Order Mennonite Church tenets:

1) Technically, any microcontroller can be programmed by directly writing a series of 0s and 1s to its input pins while it is in program mode (as typically set by other pins). However, these "machine" instructions are usually produced by an "assembler" from commands in the form of "low level" assembly language. These days, most people write the program in a higher level language such as Basic which is then compiled (normally with a computer) and "translated into the lower level language that the machine "understands." While it is feasible to write programs in the assembly language appropriate for the device, even this typically is done with a computer.

Most microprocessors are programmed with a fixture that has a serial interface, such as RS-232, and some of these may have an assembler onboard which would make it possible to program it via a "dumb terminal." In lieu of this, another microcontroller could be programmed to perform the assembly, but then you would be in a "chicken/egg" situation, unless there is a commercially available one or someone else is able to provide one that they developed.

One viable option is available from the Chip Factory. The Chip Factory system has been designed to provide an easy-to-learn 'entry level' step into the world of microcontrollers. The Chip Factory is a stand-alone unit that can be programmed without the use of a computer. A simple program made up of simple Basic style commands is entered into the Chip Factory memory using the on-board keypad, and then programmed into a microcontroller (which is placed in a socket on the programmer).

Unfortunately, they are located in the UK so that may be out of reach for you. The programmer costs about $200 and their phone number is: **01225 340563** or FAX: **01225 340564**.

2) There are lots of decades' old RS-232 terminals lurking around that would be suitable for your purpose. The TI Silent 700 is certainly one. It can be found for around $20 plus shipping, but in your situation they might be harder to find. Ham festivals would probably be a good source for you and there are some scheduled regularly within your area Elmira, Rochester, etc. The TI 700 uses 8-1/2 thermal paper which also might be hard to find. There are other models from that era such as the DEC LA series which use tractor feed paper, but these tend to be larger than the TI.

I believe you would prefer an alphanumeric LSD screen and these are available too. In fact, I may have

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ZD-9556 Orbital Shaker $265.00

one in my barn with a four line x 40 or 80 character monochrome LCD display and a membrane type QWERTY keyboard. I work in Rochester and would be willing to give it to you if you contact me at: 300 Meridian Centre Blvd., Suite 100, Rochester, NY 14618. I can also provide you with the dates and locations of upcoming hamfests in your area.

3) Celery LLC (**1-866-692-3537**) may have just the ticket for your email using fax. Celery looks like ordinary fax machine, but it does something that most fax machines don't — it sends and receives email. To send an email, you handwrite a note and feed it into the fax machine. The recipient then receives your note as an attachment. As for incoming emails, they come through like ordinary faxes. One year of Celery's black & white service retails for $219 with the device, or $259 for the device and one year of color service. I haven't contacted them but they may have a plan that would work with your existing fax machine at a lower cost.

Other possible options are the "Mailbug" from Landel that uses an integrated keyboard and monochrome LSC display which connects directly to the phone line. Main: **(408) 360-0480**; Customer Support: **(408) 360-0490**; Fax: **(408) 360-0499**.

Finally, Presto is a new online printing service that presents an innovative solution: The service allows you to send email, including photo attachments, to a Presto email address. There, the service converts the email and any attached photos into customizable layouts ready to print out on a $150 HP A10 Printing Mailbox (currently the only Presto-enabled device). The printer receives and prints information automatically. Because the Printing Mailbox connects to the phone line, it doesn't require an Internet connection or a computer to automatically check for and print content — which it does at intervals that you schedule during setup. The Presto Service costs $10 per month, or $100 annually. Phone: **800-919-3199**.

John Jones
Rochester, NY

#2 1) In the old days, you programmed your processor from the front panel. Switches and paper tape were the way things were done. For a while, many microcontroller programmers were done using identical microcontrollers to program the other one. It can be done; a boot strap approach would be the best. Start with maybe something like the 1802 based ELF that was featured recently in *Nuts & Volts*. Build a small controller board from that to load your microcontroller code into. Then, using a serial or parallel programmable part (PIC, AVR, Freescale, etc.), the elf could do the programming. Once the microcontrollers can be programmed, build an easier programmer for them, maybe including an assembler/debugger.

2) I think I have an old Televideo terminal in unknown state in my storage room. I used the heck out of it on CP/M machines, 15 years ago. Recently (last couple years or so), I remember seeing RS-232 based terminals using a PIC chip and an LCD display. The TI Silent 700 was a thermal printer terminal, sort of like an old teletype; no video display, that sometimes had an acoustic coupler on it. I think its max speed was 300 baud, but could have been faster. The ones I used were always connected to the modem.

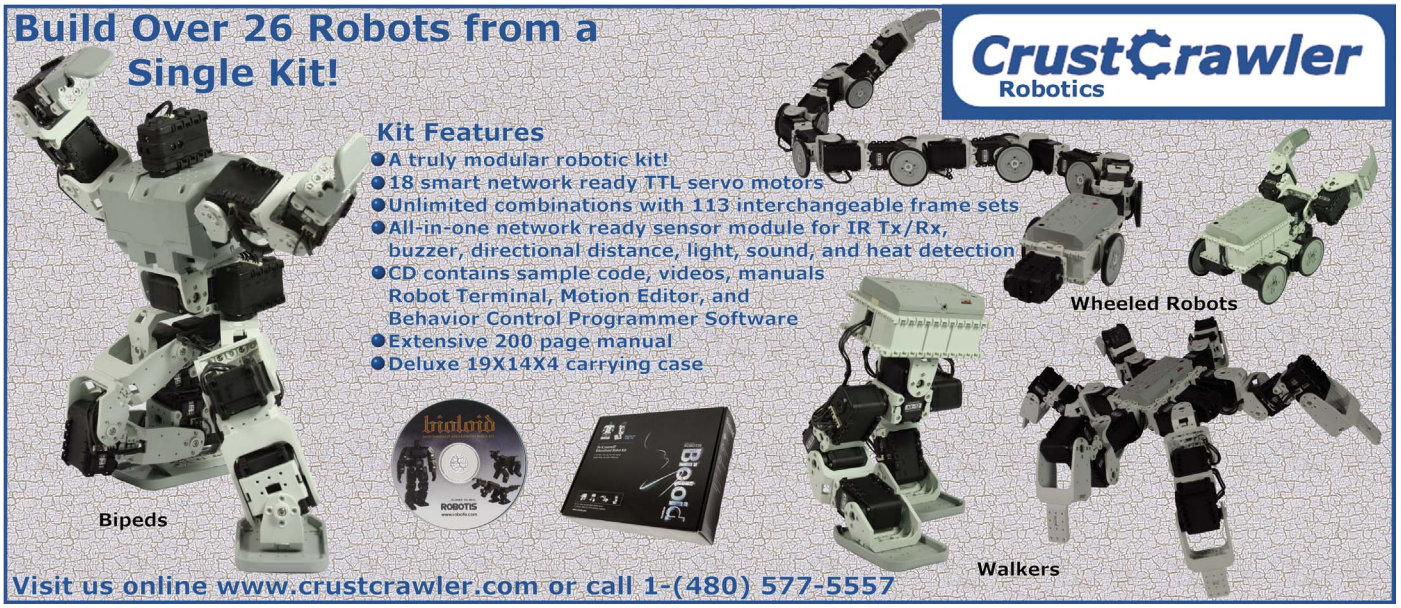
3) Most PCs can configure their modem to fax mode, and some software can be used to have the fax modem work as a printer device. There are fax services that will send a received fax as an email attachment. Yes, it is theoretically possible to use the fax as a way to send and receive email, and not too cumbersome.

Tom Brusehaver
Bloomington, MN

[#2072 - February 2007]

I'm looking for a circuit diagram that will let me know the status of a fuse in a 12 VDC circuit and 120 VAC circuit. It must light an LED to show that the fuse has blown. It would be used to monitor automotive fuses and the fuses for an amateur radio station.

#1 Simply place an LED (check for polarity) directly across the 12 VDC fuse with a 510 ohm resistor value for



12 volts. If the fuse blows, the LED will become part of the load and glow. To monitor the 120 VAC fuse, place an appropriate 120 VAC bulb (preferably a neon bulb with 22K resistor) directly across the fuse. If the fuse blows, the bulb will light. Run the wires for the LED and AC bulb from some convenient panel for monitoring, if appropriate to your cause.

John F. Mastromoro
Saint Johnsville, NY

#2 The standard way to detect a blown fuse is with an indicator circuit wired across the fuse. For 120 VAC, use a neon indicator lamp with a built-in resistor, as shown in Figure 1. For a 12 VDC circuit, use an LED with a resistor, as shown in Figure 2.

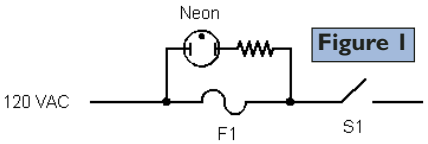


Figure 1

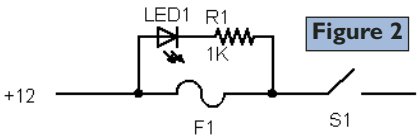


Figure 2

These indicators require that a load be connected and turned on in order to indicate a blown fuse. If you want to detect a blown fuse with or without such a load, use the circuit in Figure 3. This circuit holds the transistor off by applying + to the base through the diode and the 1K resistor. If the fuse blows, the transistor is turned on by the 27K resistor from base to ground, and the LED lights. The diode from +12 to the emitter compensates for the voltage drop in the diode between

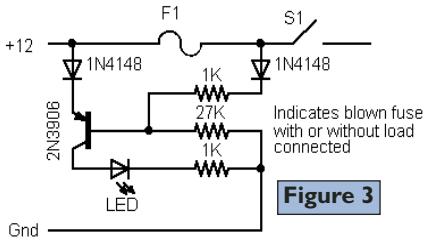


Figure 3

the 1K base resistor and the fuse.

For a 120 VAC blown fuse indication without a load, use an NE-2 neon bulb without a built-in resistor (like part #36NE002 from Mouser). Connect the bulb in-series with a 100K resistor and install that across the fuse as shown in the first diagram. Then add a 100K 1/2 watt resistor from the fuse to the other side of the AC line.

Ed Schick
Harrison, NY

#3 I designed this circuit (Figure 1) back in 1990 for a competition car stereo fuse panel. It is quite clever as it gives an instant visual indication of the fuse condition. GREEN means GOOD and RED means BAD. Later, I modified it slightly, (Figure 2) for use on AC fuses. I have also used it with the new dual LEDs, super bright LEDs, and even jumbo 10 mm LEDs.

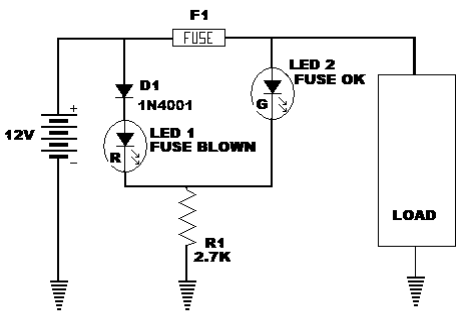


FIG. 1 BLOWN FUSE INDICATOR FOR DC VOLTAGE

The circuits (Figure 1 and Figure 2) are based on Kirchhoff's voltage law where, if a circuit is opened up (blown fuse, open switch, etc.), the source voltage will be seen across the open. Normal voltage through the fuse fires LED2 (green) as long as the fuse is good. D1, a standard rectifier diode, prevents LED1 from firing except when a fuse blows. R1, in both circuits, serves as a current limiter for about 3.5 mA. I have also utilized this same circuit as a toggle switch on/off indicator, as well. Just substitute a switch into the circuit where the fuse is.

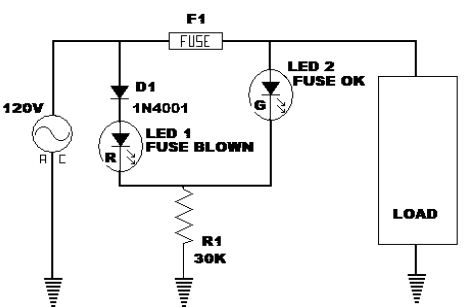


FIG. 2 BLOWN FUSE INDICATOR FOR AC VOLTAGE

Note: The circuit was designed using whatever LEDs I had laying around the shop at the time. These just happened to illuminate brightest at 3.5 mA so I used Ohm's law to calculate 2.7K ohms as a current limiting resistor. Also, on the AC circuit, since the LEDs are rectifying the signal, they will require about 10 VAC @ 3.5 mA to Illuminate, therefore a 30K resistor is needed for 120 VAC. You will need to adjust the resistance values slightly for modern LEDs, especially if you use a jumbo LED or any of the super bright LEDs.

KI4NNH - Jerry Ginn
Franklin Springs, GA

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- High Performance: 2000 readings/sec
- Multi-Point Scan
- 19 Full-Featured Functions
- Dual Displays with 3-color Annunciators
- Noise Immunity.
- Built-in USB and GPIB (optional) Interfaces
- Easy & Free PC applications
- 6 1/2 Digits M3500A Specifications
- Optional Accessories
- Designed with 7-1/2 digit techniques to provide user a stable, faster and accurate measurement.
- 1000VDC / 750VAC

PICOTEST

Compare Price & Specs with the Agilent 34410A !

Item# M3500A

$689.00

Details at Web Site

> Test Equipment > Digital Multimeters

Protek 100,000 Count Programmable Data Logging DMM

A power house DMM with 100,000 count accuracy and a built-in data logger that will help you find intermittant problems and monitor equipment while you are busy working on other jobs. The D620 can record and store in it's own internal memory up to 37,300 time stamped data values in all functions by simply pressing a button.

- True RMS measurements for AC
- RS-232C interface with personal computer.

Special **$169.00!**

Item# PROTEK D620

Details at Web Site > Test Equipment > DIGITAL MULTIMETERS

Dual Output DC Bench Power Supplies

High stability digital read-out bench power supplies featuring constant voltage and current outputs. Short-circuit and current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance and long life.

As Low As **$93.00!**

- Source Effect: $5x10^{-4}$=2mV
- Load Effect: $5x10^{-4}$=2mV
- Ripple Coefficient:: <250uV
- Stepped Current: 30mA +/- 1mA

HOT ITEM!

*All 3 Models have a **1A/5VDC Fixed Output** on the rear panel*

CSI3003X-5: 0-30v/0-3amp 1-4: **$105.95** 5+: **$99.50**

CSI5003X5: 0-50v/0-3amp 1-4: **$114.95** 5+: **$109.00**

CSI3005X5: 0-30v/0-5amp 1-4: **$119.00** 5+: **$114.00**

Details at Web Site > Test Equipment > Power Supplies

Triple Output Bench Power Supplies

with Large LCD Displays

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1ea. fixed output @ 5VDC@3A
- Source Effect: $5x10^{-4}$=2mV
- Load Effect: $5x10^{-4}$=2mV
- Ripple Coefficient: <250uV
- Stepped Current: 30mA +/- 1mA
- Input Voltage: 110VAC

CSI3003X3: 0-30VDCx2 @3A **$188.00** 5+: **$183.00**

CSI3005XIII: 0-30VDCx2 @5A **$239.00** 5+: **$229.00**

Details at Web Site > Test Equipment > Power Supplies

Circuit Specialists, Inc. 220 S. Country Club Dr., Mesa, AZ 85210
800-528-1417 / 480-464-2485 / FAX: 480-464-5824

ESD Safe CPU Controlled SMD Hot Air Rework Station

The heater and air control system are built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.

Item# CSI825A++

- CPU Controlled
- Built-in Vacuum System
- Temperature Range:100°C to 480°C / 212°F to 896°F
- 15-Minute Stand-By temperature "sleep" mode
- Power:110/120 VAC, 320 W maximum

Sale $149.00!

Details at Web Site > Soldering Equipment & Supplies

Breadboard / Power Supply / MultiFunction DMM Bundle

Provides the user with a quick and efficient system for breadboarding electronic circuits. Comes with three built-in regulated power supplies along with a deluxe, easy-to-use breadboard. Included is a multifunction DMM with 1000VDC, 750VAC, frequency, resistance, diode test, audible continuity, transistor check,temperature, and capacitance.

A Super Deal!

Only $69.99!

Details at Web Site
> Breadboards & Prototyping Boards

Powered Breadboard w/out DMM: $69.00

Item#: PBB272-DMM: $69.99!

Powered Breadboard w/Multifunction DMM (CSIMS8264)

You Get The DMM for an Extra $.99

Digital Storage Oscilloscope Module

PC based Digital Storage Oscilloscope, 200MHz 5GS/s equiv. sampling USB interface

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC basedscope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

Details & Software Download at Web Site

Price Breakthrough!

> Test Equipment > Oscilloscopes/Outstanding Prices

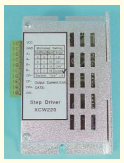
Item# 200DSO Only $819.00

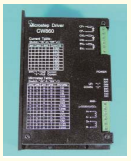
Stepper Motors

Part #:	Motor Frame Size:	Holding Torque:	Price:
42BYGH404	NEMA 17	3.4kg.cm/47oz.in	$17.95
57BYGH207	NEMA 23	8kg.cm/111oz.in	$24.95
57BYGH303	NEMA 23	15kg.cm/208oz.in	$29.95
57BYGH405	NEMA 23	20kg.cm/277oz.in	$34.95
85BYGH350B-03	NEMA 34	48kg.in/665oz.in	$79.95
85BYGH350C-03	NEMA 34	63kg.cm/874oz.in	$119.95

Stepper Motor Controllers 2 Phase Microstepping

Stepper Motor Driver (Bi-polar & Unipolar Motors)





Part #:	Dimensions:	MicroStep:	Price:
XCW220	100mm x 61mm x 19mm	1(200), 1/2(400), 1/4(800), 1/8(1600)	$39.95
CW220	99mm x 65mm x 30mm	1/2(400), 1/8(1600)	$49.95
CW230	115mm x 72mm x 32mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800)	$59.95
CW250	140mm x 94mm x 45mm	1(200), 1/2(400), 1/8(1600)	$69.95
CW860	147mm x 97mm x 30mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800), 128(25600), 1/5(1000), 1/10(2000), 1/25(5000), 1/50(10000), 1/125(25000), 1/250(50000)	$119.95

Protek

Protek 2.0 & 2.9GHz Field Strength Analyzers

- Frequency Range : 100KHz ~ 2900MHz (2060MHz for 3201N)
- WFM/NFM/AM/SSB modulated signals may be measured.
- Sweep Trigger Mode: Free Run, Single Run, Continuous Wave, Squelch Run
- Sweep Speed: 500 to 2000msec
- PLL tuning system for precise frequency measurement and tuning
- Built-in Frequency Counter
- RS232 interface

3290N

New Rev. Now Available

Item#'s 3290N & 3201N

Details at Web Site

> Test Equipment > RF Test Equipment

Special
$1899.00 (for 3290N)
$1374.00 (for 3201N)

Outdoor Color Speed Dome Camera

- 1/4" SONY Exview CCD
- 768(H) x 494(V) effective pixels
- Horizontal Resolution: 480TV lines
- Up to 80 preset points
- Line scanning
- Continuous 360° horizontal rotation
- Vertical rotation: 0-100°
- RS485 control interface
- Min. Illumination: 0.1Lux (color) / 0.001Lux (B&W)

Item# VC-EX861 $899.00

Details at Web Site

Shown with optional wall mount

> Miniature Cameras(Board,Bullet,Mini's, B/W, Color)

SONY Super HAD CCD Color Weatherproof IR Cameras

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor:1/3" SONY Super HAD CCD
- Horizontal Resolution: 480TV lines
- Min. Illumination: 0Lux

480 TV Lines Resolution

Item# VC-827D: $132.00

SONY Super HAD CCD™ equipped camera's feature dramatically improved light sensitivity

SONY Super HAD CCD B/W Weatherproof IR Camera

- Day & Night Auto Switch
- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# VC-317D: $59.50

Details at Web Site

SONY Super HAD CCD Color Camera

- Weather Proof
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 1Lux/F1.2

Item# VC-805: $53.95

SONY Super HAD CCD Color Weatherproof IR Camera

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# VC-819D: $62.50

> Miniature Cameras(Board,Bullet,Mini's, B/W, Color)

Visit our website for a complete listing of our offers. We have over 8,000 electronic items on line @ www.CircuitSpecialists.com. PC based data acquisition, industrial computers, loads of test equipment, optics, I.C's, transistors, diodes, resistors, potentiometers, motion control products, capacitors,miniature observation cameras, panel meters, chemicals for electronics, do it yourself printed circuit supplies for PCB fabrication, educational D.I.Y. kits, cooling fans, heat shrink, cable ties & other wire handleing items, hand tools for electronics, breadboards, trainers, programmers & much much more! *Some Deals you won't believe!*

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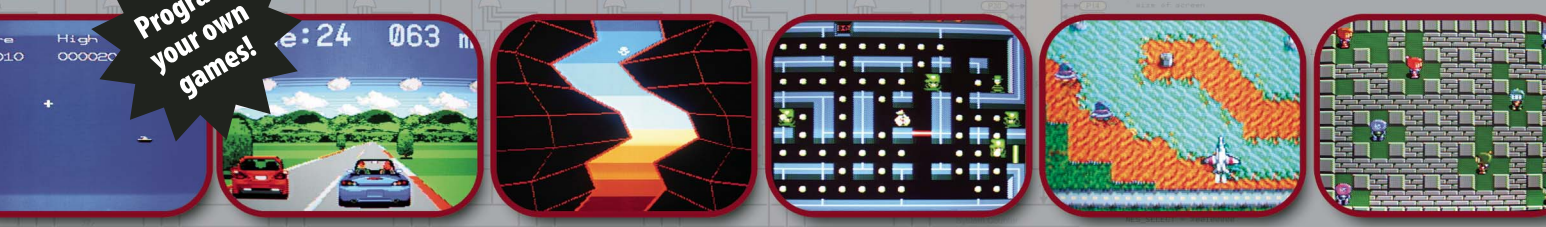

HYDRA

Game Development Kit

Low price! Now only $199.95!

Develop games, graphics and media applications with the Propeller™ Powered HYDRA™ Game Console. Only basic programming experience in any BASIC or C-like language is required to use this kit. All of the hardware and software is included, along with a comprehensive book on game programming for the Propeller microcontroller in Spin™ and assembly language. Additionally, the HYDRA hardware is covered in detail with schematics, descriptions, and tips allowing you to take full advantage of its resources, including its expansion port and game card. ***Here's what you'll find inside...***

- Setting up the Propeller Tool Software IDE
- In-depth discussion of the Propeller chip at the register level
- Spin Language overview and programming
- Assembly Language programming
- HYDRA Architecture and circuit descriptions
- 2D graphics and animation programming
- Game algorithms and software patterns
- Sound programming including PCM techniques
- Input device programing for keyboard, mouse, and game controller
- Optimization techniques for game programming
- Basic physics modeling for games
- Artificial intelligence techniques
- Mathematics for games including vectors and affine transformations
- Dozens of demos showing all topics discussed

HYDRA Game Development Kit (#32360; $199.95)

Order the HYDRA Game Development Kit (#32360; $199.95) online from Parallax.com, or call toll-free 888-512-1024 (Mon-Fri, 7am-5pm, PT)

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